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ontario hydro
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To Mr. H.N. Isaac
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LAC DU BONNET GEOMECHANICAL
TEST RESULTS

D.A. McKay

This is the third in a series of reports on the physical properties of rocks. The end result of this project is a data bank of geomechanical properties of various rock types to determine their suitability as a host medium for a radioactive waste repository. This program is a joint effort by Ontario Hydro and CANMET.

INTRODUCTION

The third phase of the joint Ontario Hydro/CANMET study is a continuation of the determination of the geomechanical properties of selected rock cores from various sites throughout Ontario. The properties determined are:

- 1) dilational wave velocity
- 2) Young's modulus
- 3) Poisson's ratio
- 4) uniaxial compressive strength
- 5) Brazilian tensile strength

TESTING METHODS

Dilational Wave Velocity Measurements

The testing equipment for this test is shown in Figures 1 and 2. It consists of two transducers containing piezoelectric crystals and a Pundit Unit which acts as a pulse generator, signal amplifier and time display. The transducers used in this series of tests are capable of determining P and S wave velocities and because they are very sensitive to the vibration of hydraulic systems a hand operated hydraulic pump was used. Loads were applied in the same increments as in the first series of testing up to a

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maximum load of 40.5 kN due to the structural limitations of the transducers. Measurements were taken during both the loading and unloading cycles.

Young Modulus, Poisson's Ratio and Compressive Strength

The test specimens were prepared according to ASTM specifications D2938-71/1/. Strain measurements were made using a deformation jacket shown in Figure 3. The Young's modulus was calculated as the tangential modulus at 50% of the ultimate compressive strength. Each specimen is subjected to three loading and unloading cycles with the reported Young's modulus and Poisson's ratio being the average value of the final two cycles.

Brazilian Tensile Strength Tests

These tests were performed on specimens selected by EMR and were tested according to ASTM specification C496-71/2/. The specimen thickness to diameter ratio that was used was 0.5:1.0. The structure of many of the specimens showed a preferred orientation to determine the degree of strength anisotropy.

RESULTS

A summary of test results for each test group is given in Tables I-III. Plots of P wave velocity versus load are given in Appendix I. Typical stress strain curves are shown in Appendix II. Plots relating Young's modulus to compressive strength according to the system by Deere and Miller/3/ are given in Figure 4. The term modulus ratio used in this system is defined as

$$\text{modulus ratio} = \frac{\text{tangential Young's modulus at 50\% ultimate strength}}{\text{uniaxial compressive strength}}$$

where high modulus ratio > 500

medium modulus ratio 200 < mod ratio < 500

low modulus ratio < 200

SUMMARY

Dilational Wave Velocity

The stress-velocity curves are contained in Appendix I and the test results are contained in Table I. The P wave velocities ranged from 2.866 km/sec to 6.064 km/sec under 0 MPa stress. The P wave velocities ranged from 5.000 km/sec to 6.392 km/sec under a stress of 28 MPa. The per cent increase in the P velocity from 0 MPa to 28 MPa varied from 3.2% to 75.0%. Samples P3567-1 to P3567-10 show a fairly linear increase in P velocities whereas sample the plots for samples P3567-11 to P3567-16 have a distinct curve. This group of samples has lower P wave velocities than the first group and also show a greater per cent increase in the P velocity. The P3567-1 to P3567-10 group has an P wave increase range of 3.2% to 24.4% while the P3567-11 to P3567-16 group has a P wave increase range of 37.8% to 75.0%.

Compressional Test Results

The results from these series of tests includes values for Young's modulus and Poisson's ratio as well as the compressive strength. The stress strain curves are contained in Appendix II and the test results are contained in Table II.

Young's Modulus (E)

The values for Young's modulus range from 61420 MPa to 85982 MPa. The results indicate two different groups. The first group consists of samples P3567-1 to P3567-8 with E values ranging from 74520 MPa to 85982 MPa. The second group of samples P3567-10 to P3567-16, ranges from 61420 MPa to 68610 MPa. The stress-strain curves indicate that the first group behaves elastically or slightly plastic-elastic and the second group behaves plastic-elastic. The plot in Figure 4 shows this grouping. Both groups are classified as having a medium modulus ratio.

Poisson's Ratio

The values of Poisson's ratio varies from 0.23 to 0.36.

Compressive Strength

The compressive strengths of this set of cores ranged from 146.16 MPa to 248.21 MPa. The results are plotted in Figure 4 and show that all but two of the samples are classified as high strength. The remaining two samples are classified as having a very high strength.

Tensile Strength

Two samples P3567-4 and P3567-9 were cut into. Brazilian tensile strength specimens. Four samples were obtained from each core. The test results are given in Table III. The strengths ranged from 11.75 MPa to 16.82 MPa. The results show a range of values for each core and do not indicate that one core was stronger than the other.

CONCLUSIONS

Sixteen core samples were tested in this project in order to determine their various geomechanical properties. It was noted that some of these cores were "pink" granite and some were "white" granite. These terms describe only the colour of the sample and not the sample mineralogy because a detailed micropetrographic examination of the various samples is beyond the scope of this project. The results do not indicate a mechanical difference

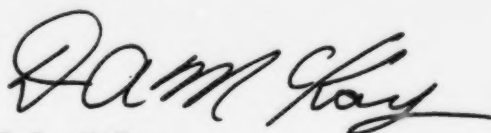
based on colour but rather depth with the samples from shallower depths being stronger and behaving elastically and the deeper samples being slightly weaker and behaving plastic-elastically.

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REFERENCES

1. ASTM "Standard Test for Unconfined Compressive Strength of Intact Rock Specimens", ASTM test D2937-71a.
2. ASTM "Standard Test for Splitting Tensile Strength of Cylindrical Concrete Specimens", ASTM test C496-71.
3. Deere, D.U. and Miller, R.P. "Engineering Classification and Index Properties for Intact Rock" Air Force Weapons Laboratory, Technical Report No AFWL-TR-65-116, Dec 1966.

TABLE I
DILATIONAL WAVE VELOCITY
TEST RESULTS

P WAVE VELOCITIES

Sample No	OMPa	28 MPa	Per Cent Change
P3567-1	5664	6130	8.2
-2	6064	6392	5.4
-3	5675	5854	3.2
-5	5179	5867	13.3
-6	5263	5962	13.3
-7	4509	5257	16.6
-8	4744	5619	18.4
-10	4317	5372	24.4
-11	2866	5016	75.0
-12	3469	5000	44.1
-13	3568	5144	44.2
-14	3384	5158	52.4
-15	3753	5170	37.8
-16	3606	5243	45.4

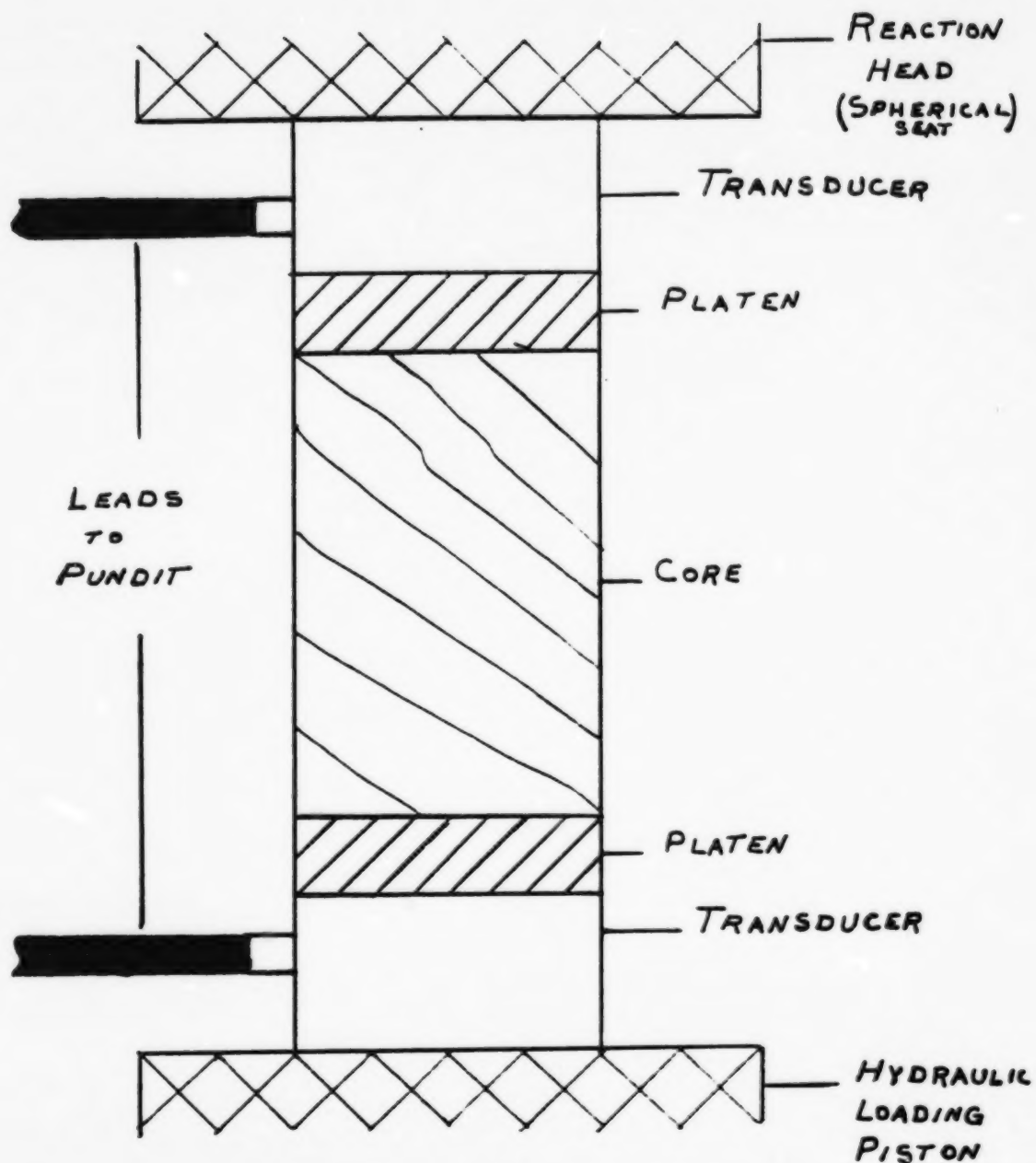
TABLE II
COMPRESSION TEST RESULTS

Sample No	Depth m	Compressive Strength MPa	Young's Modulus MPa	Poisson's Ratio
P3567-1	46.4	229.15	77140	0.24
-2	68.5	186.35	82200	0.25
-3	110.6	248.21	85982	0.29
-4 ⁺	131.3	-	-	-
-5	177.1	199.63	83440	0.27
-6	230.5	189.22	84921	0.23
-7	254.3	197.42	75020	0.26
-8	302.4	207.54	74520	0.25
-9 ⁺	357.2	-	-	-
-10	397.8	154.53	61420	0.26
-11	443.2	146.16	68610	0.30
-12	496.7	153.50	64590	0.31
-13	527.4	179.84	66350	0.32
-14	592.6	166.65	64400	0.30
-15	615.9	180.52	62380	0.32
-16	662.4	165.91	63570	0.36

+ These samples were used for Brazilian Tensile tests.

TABLE III
TENSILE TEST RESULTS

Sample No	Depth m	Tensile Strength MPa
P3567-4A	131.3	13.55
-4B		11.75
-4C		16.25
-4D		14.36
P3567-9A	357.2	12.45
-9B		13.84
-9C		14.29
-9D		16.82



P WAVE VELOCITY TEST SET UP

FIGURE 1

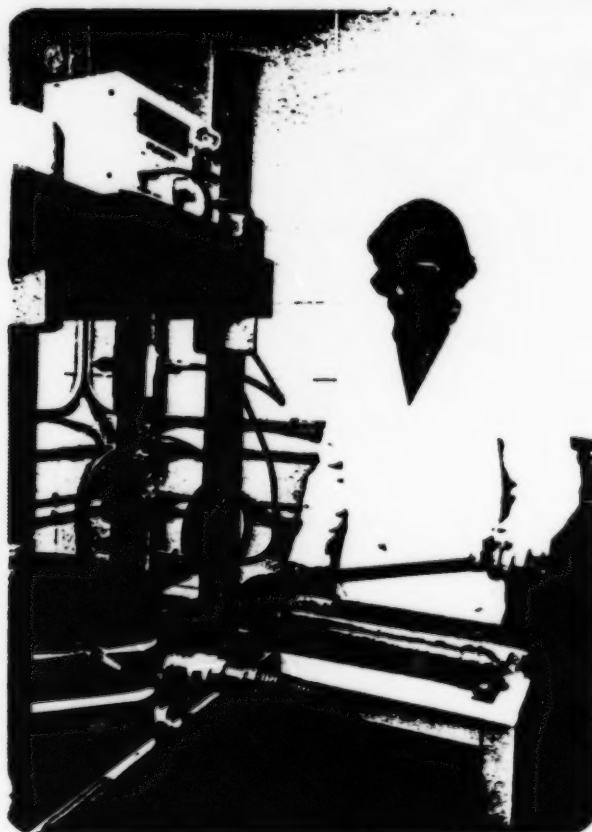


FIGURE 2
TEST SET UP FOR DILATIONAL
VELOCITY DETERMINATION

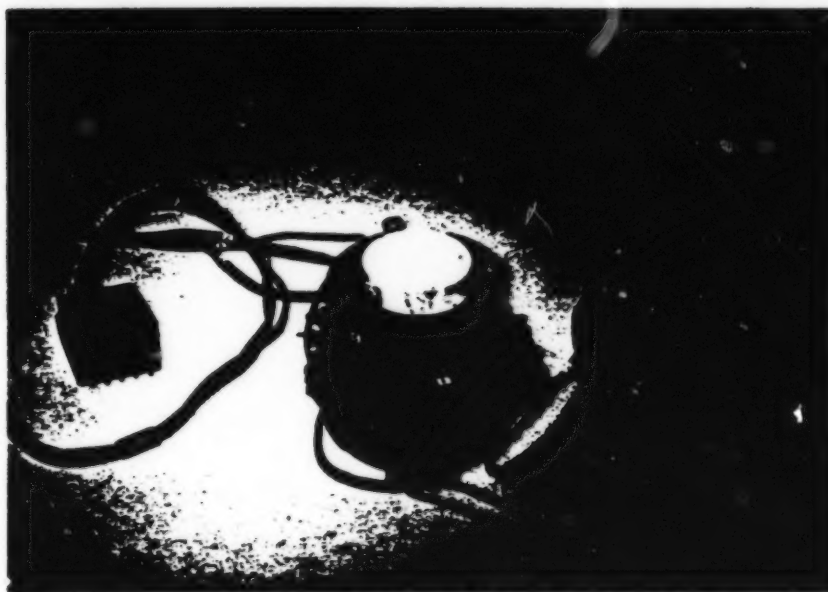
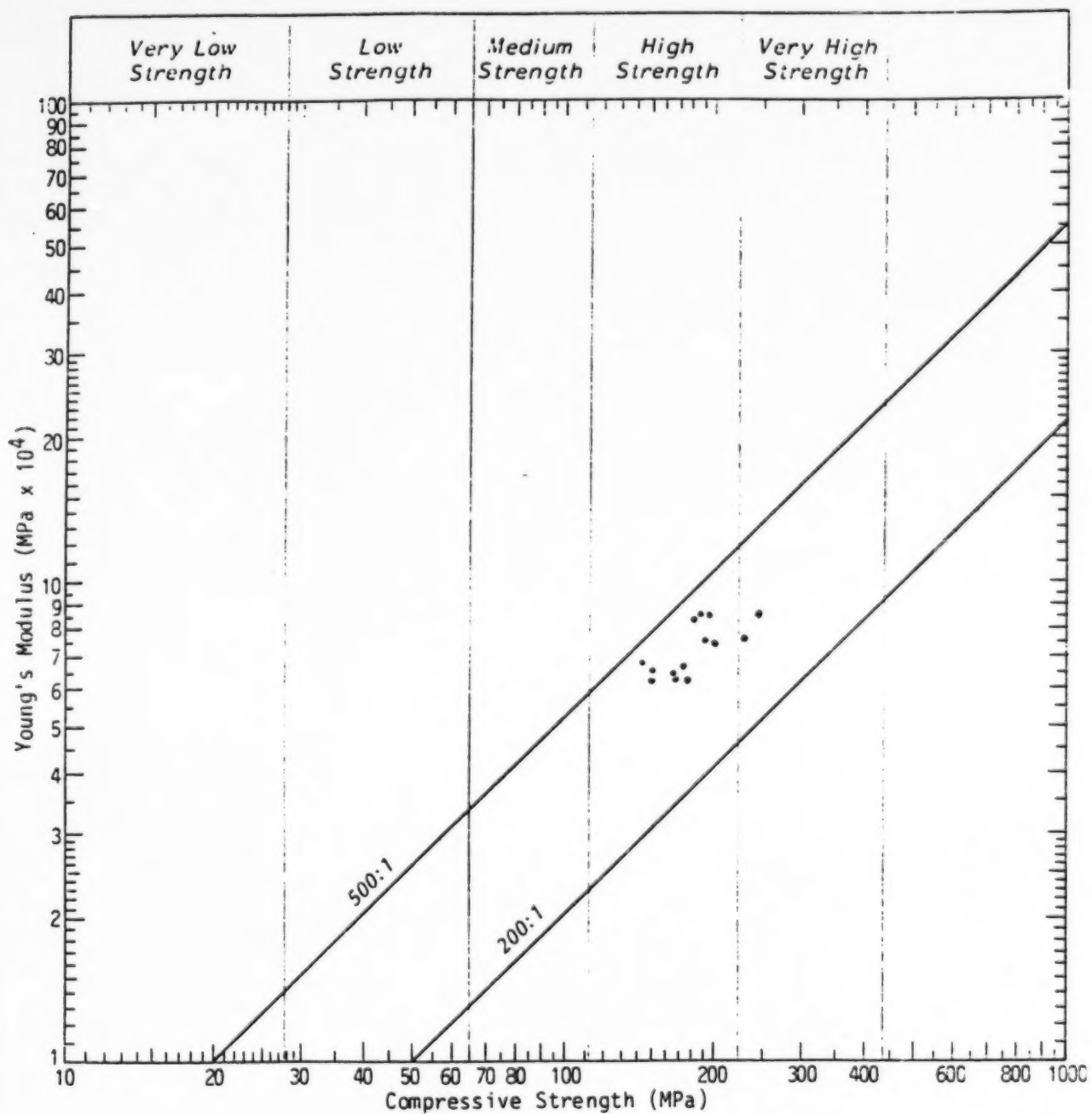


FIGURE 3
DEFORMATION JACKET

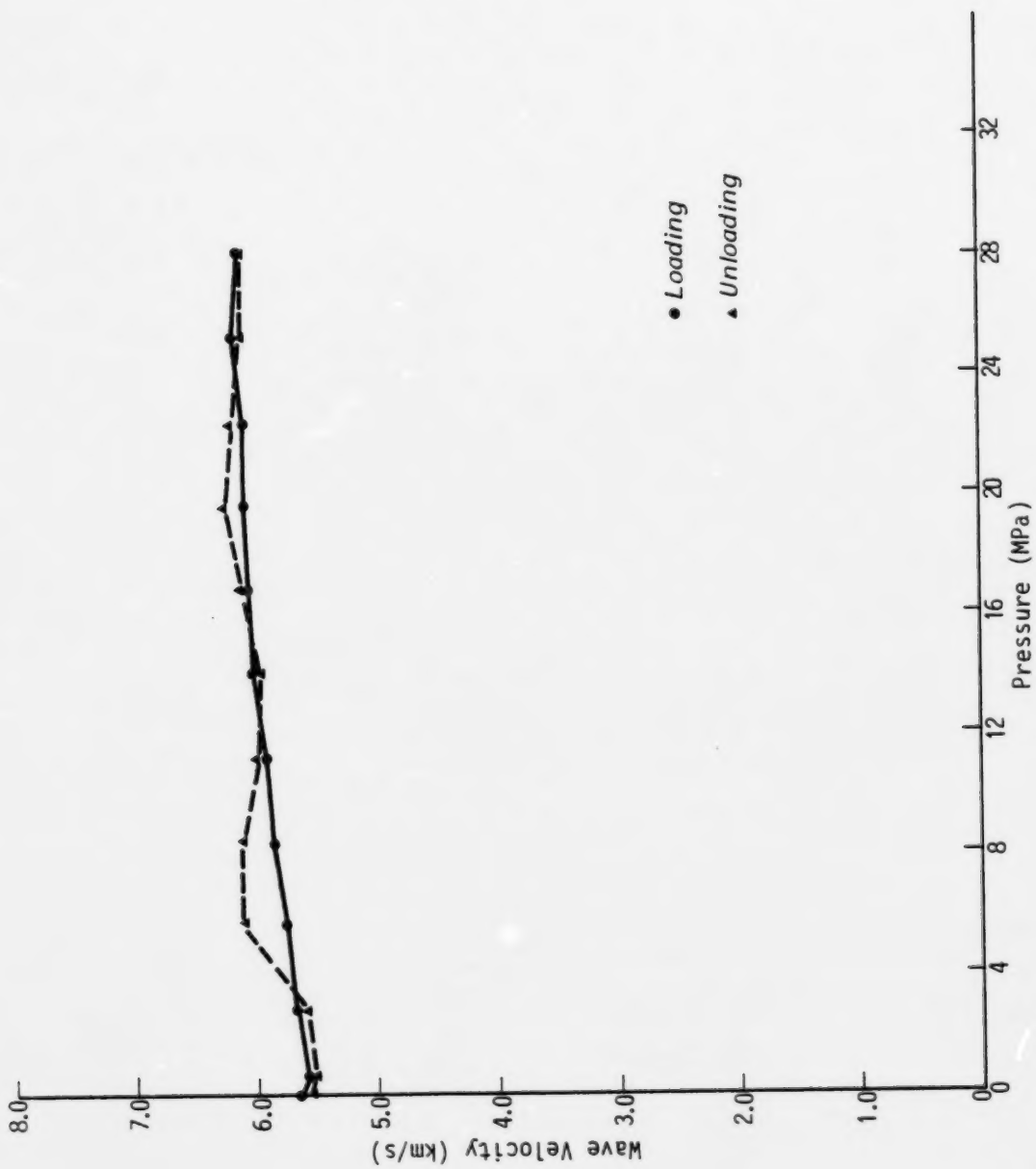


ENGINEERING CLASSIFICATION FOR INTACT ROCK
(AFTER DEERE AND MILLER, 1966)

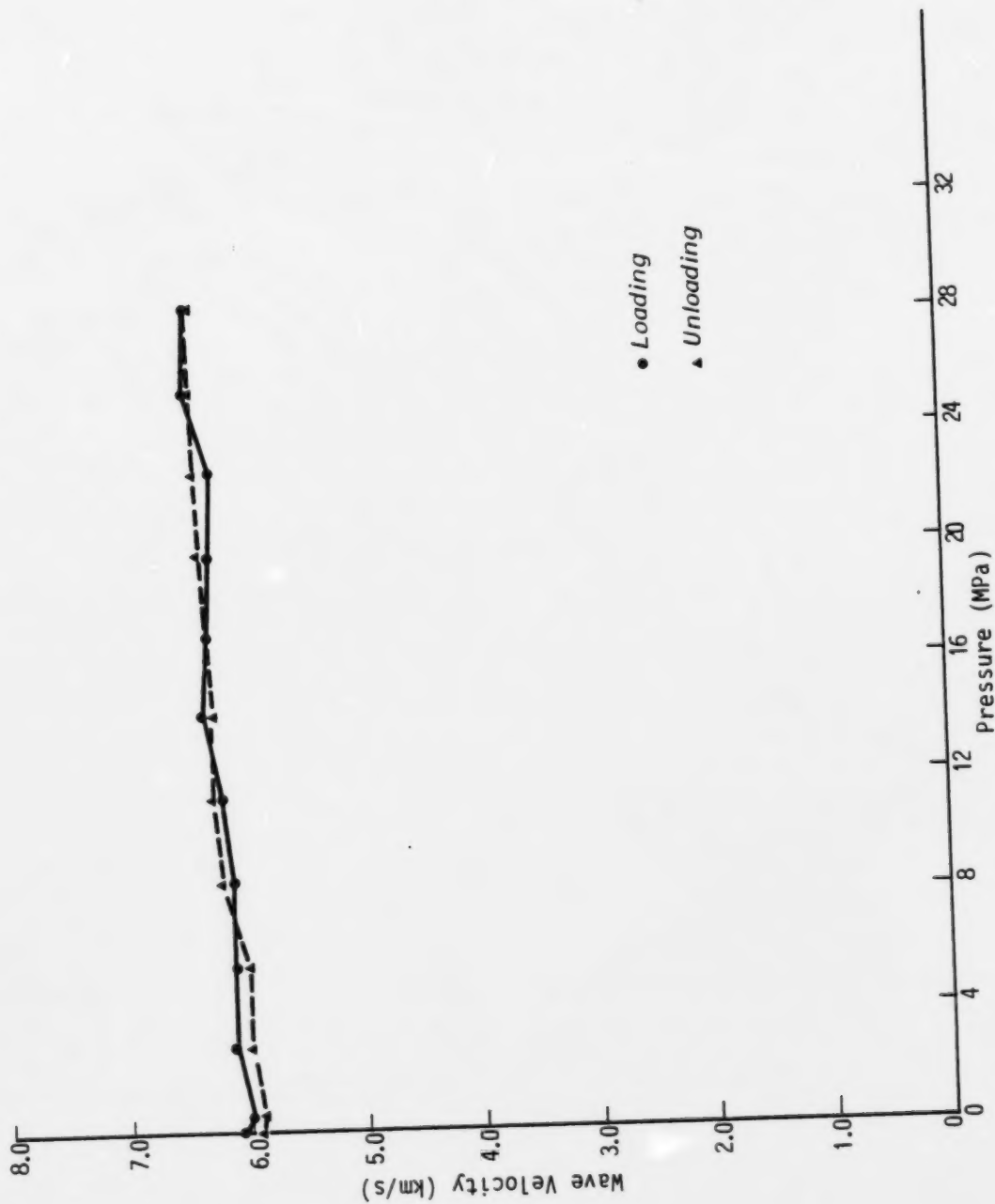
FIGURE 4

LAC DU BONNET
URL-1 CORES

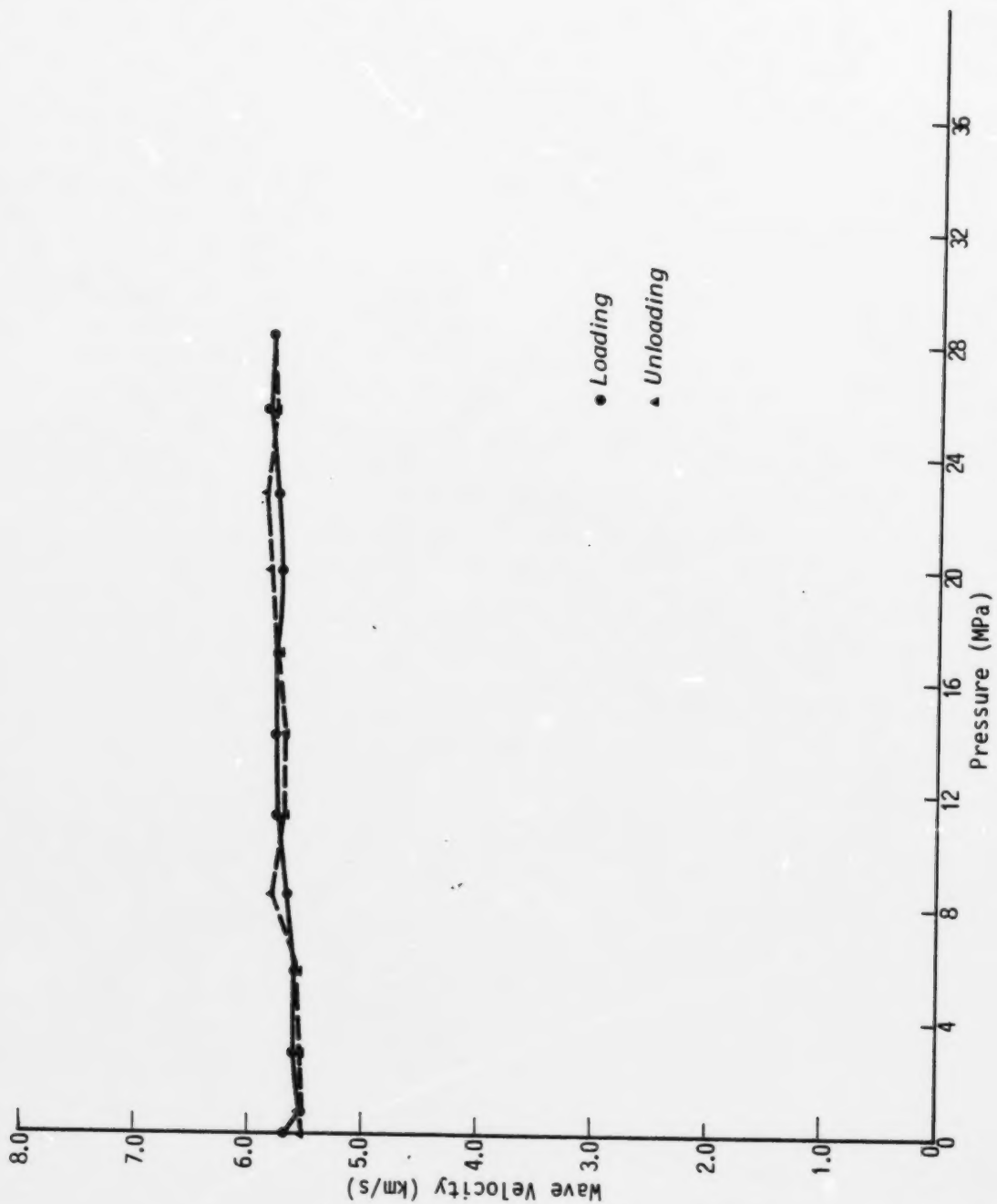
APPENDIX I



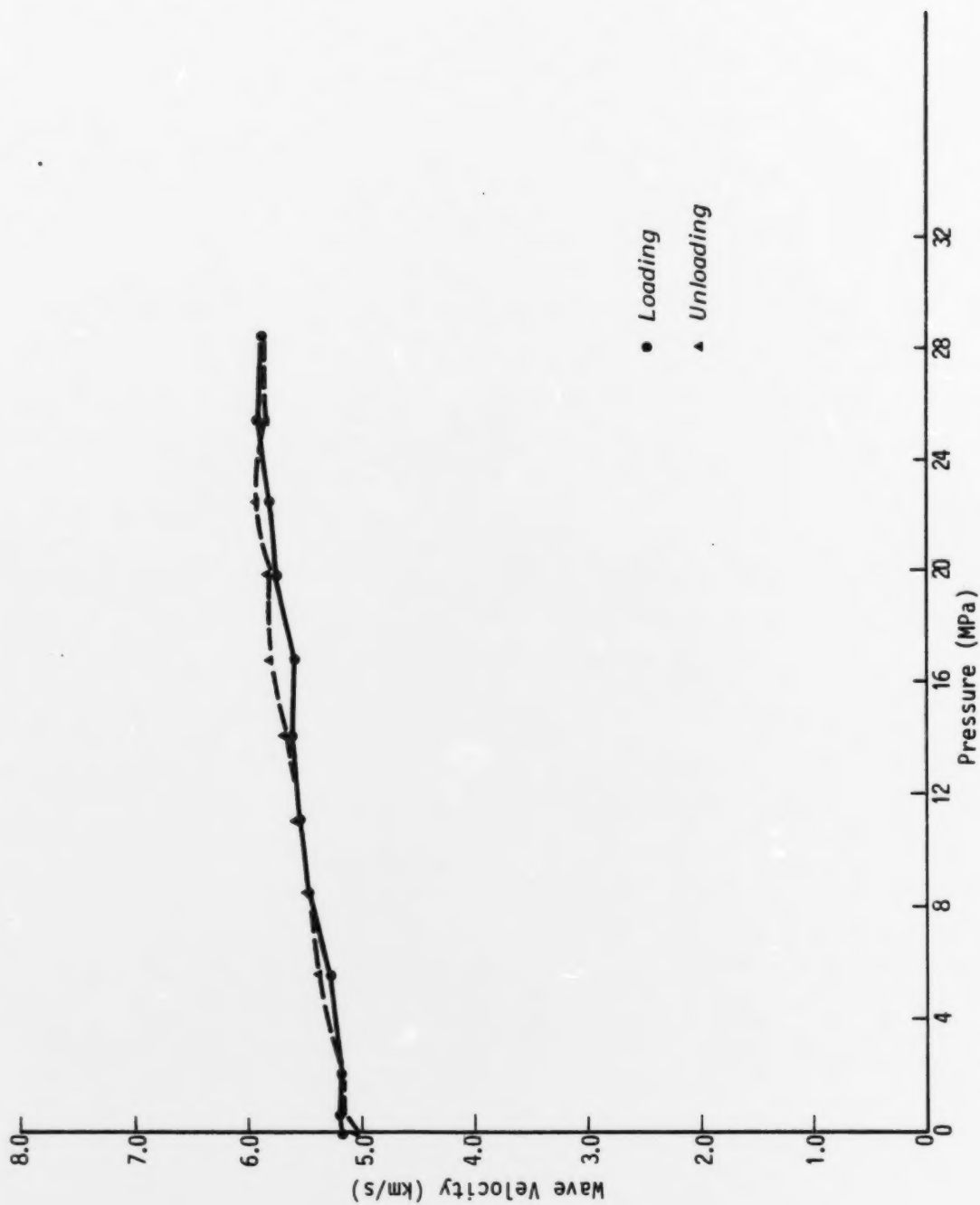
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COMPRESSIONAL WAVE VELOCITY VERSUS PRESSURE



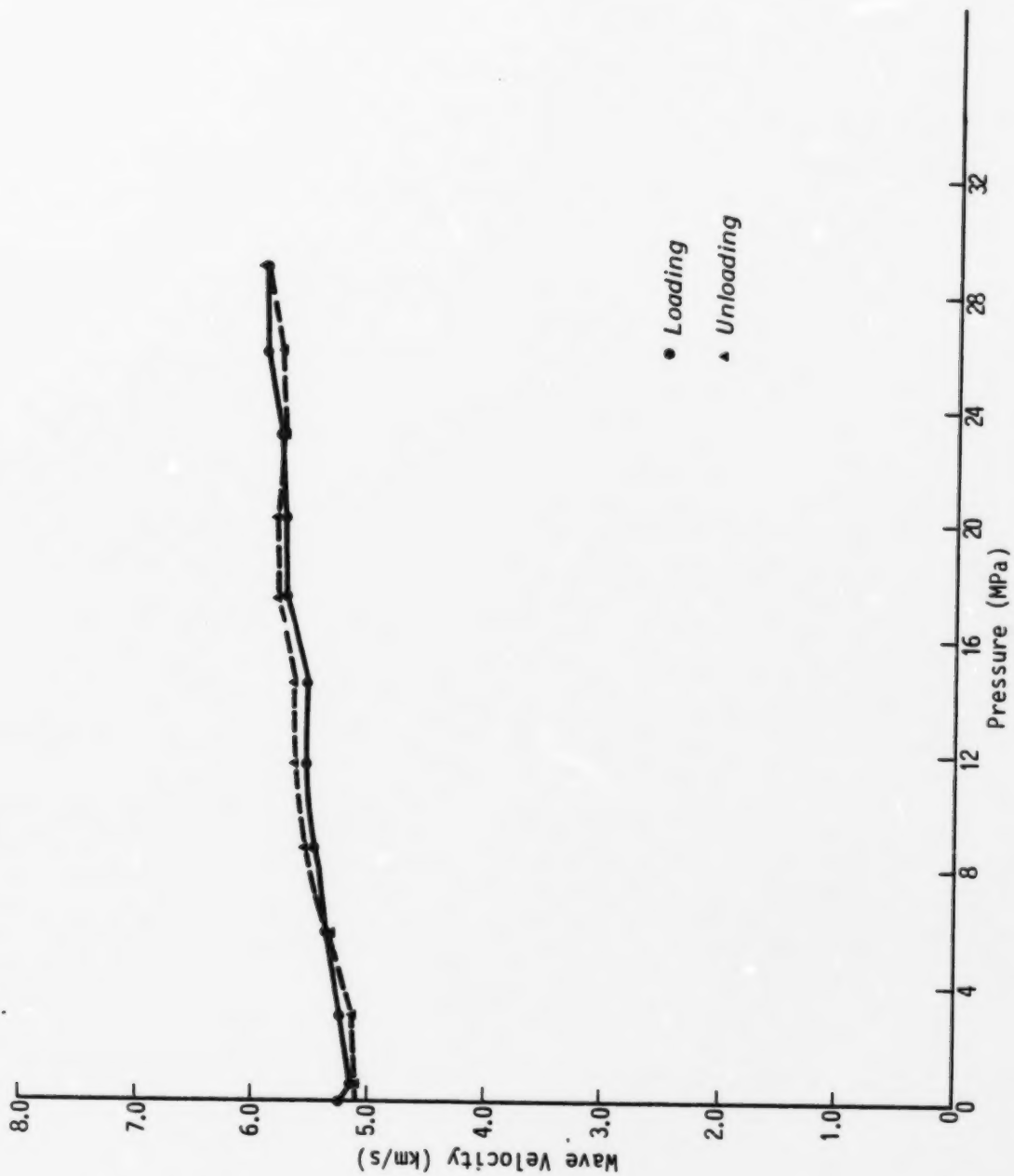
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COMPRESSIONAL WAVE VELOCITY VERSUS PRESSURE



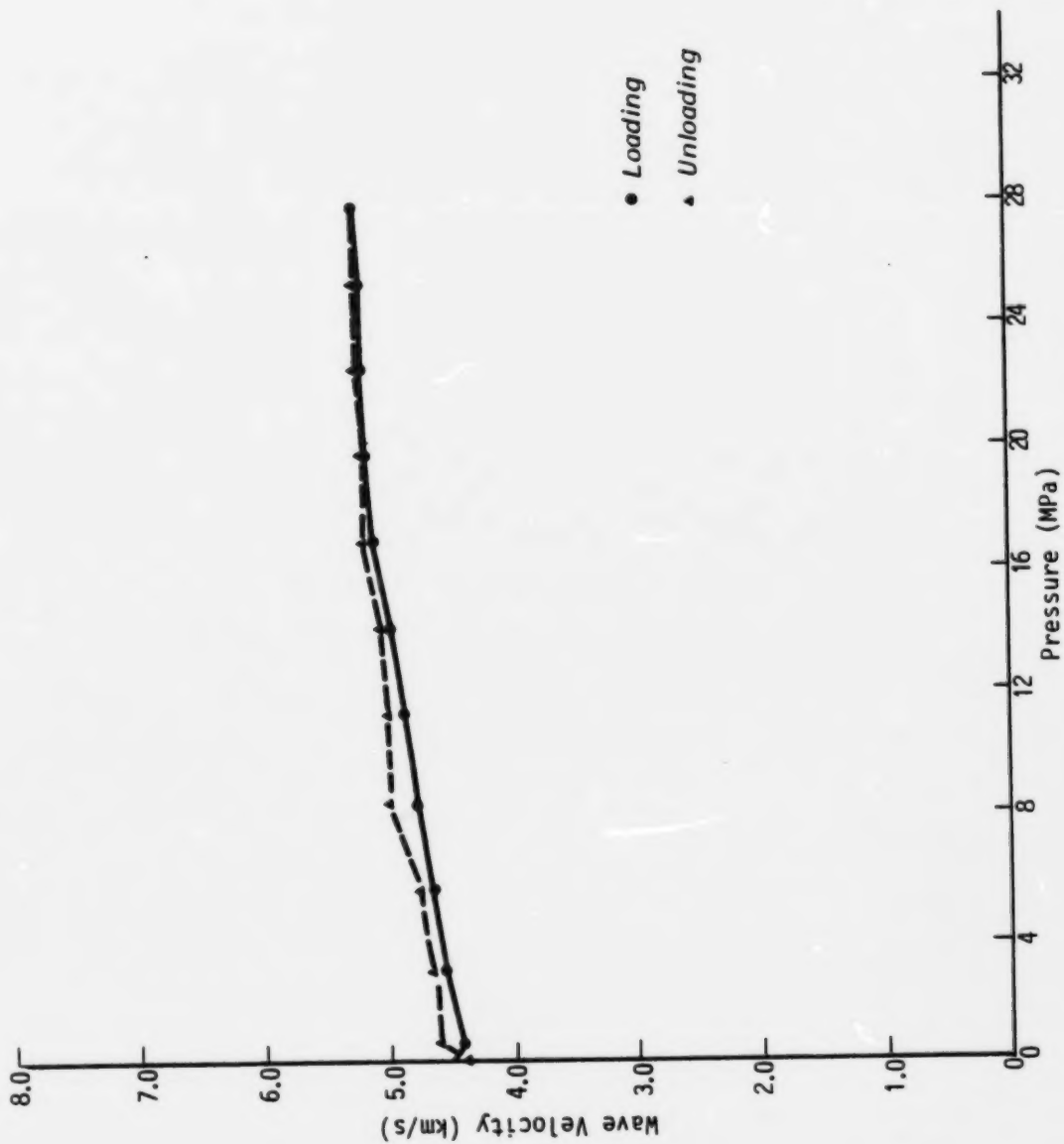
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COMPRESSONAL WAVE VELOCITY VERSUS PRESSURE



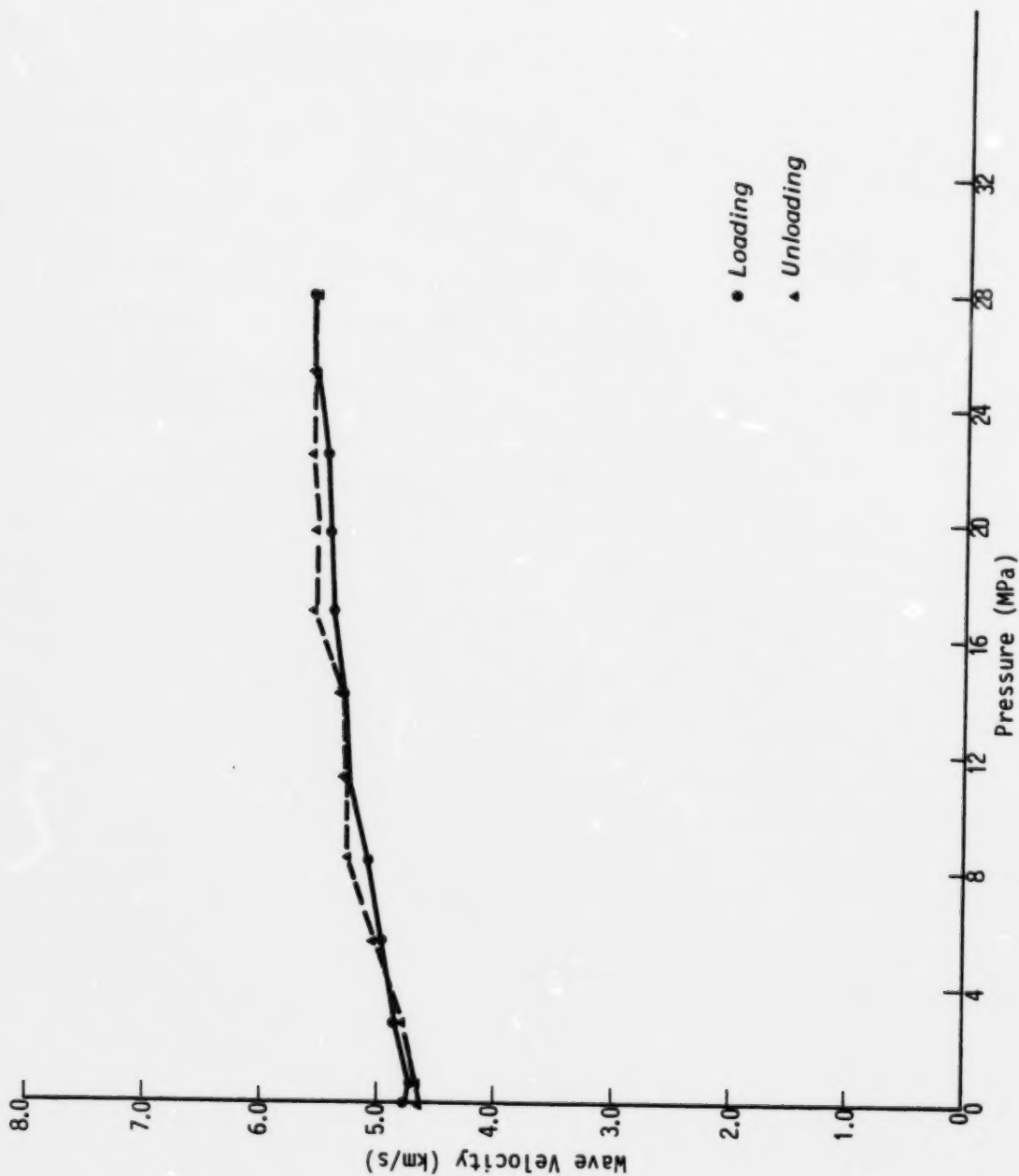
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COMPRESSONAL WAVE VELOCITY VERSUS PRESSURE



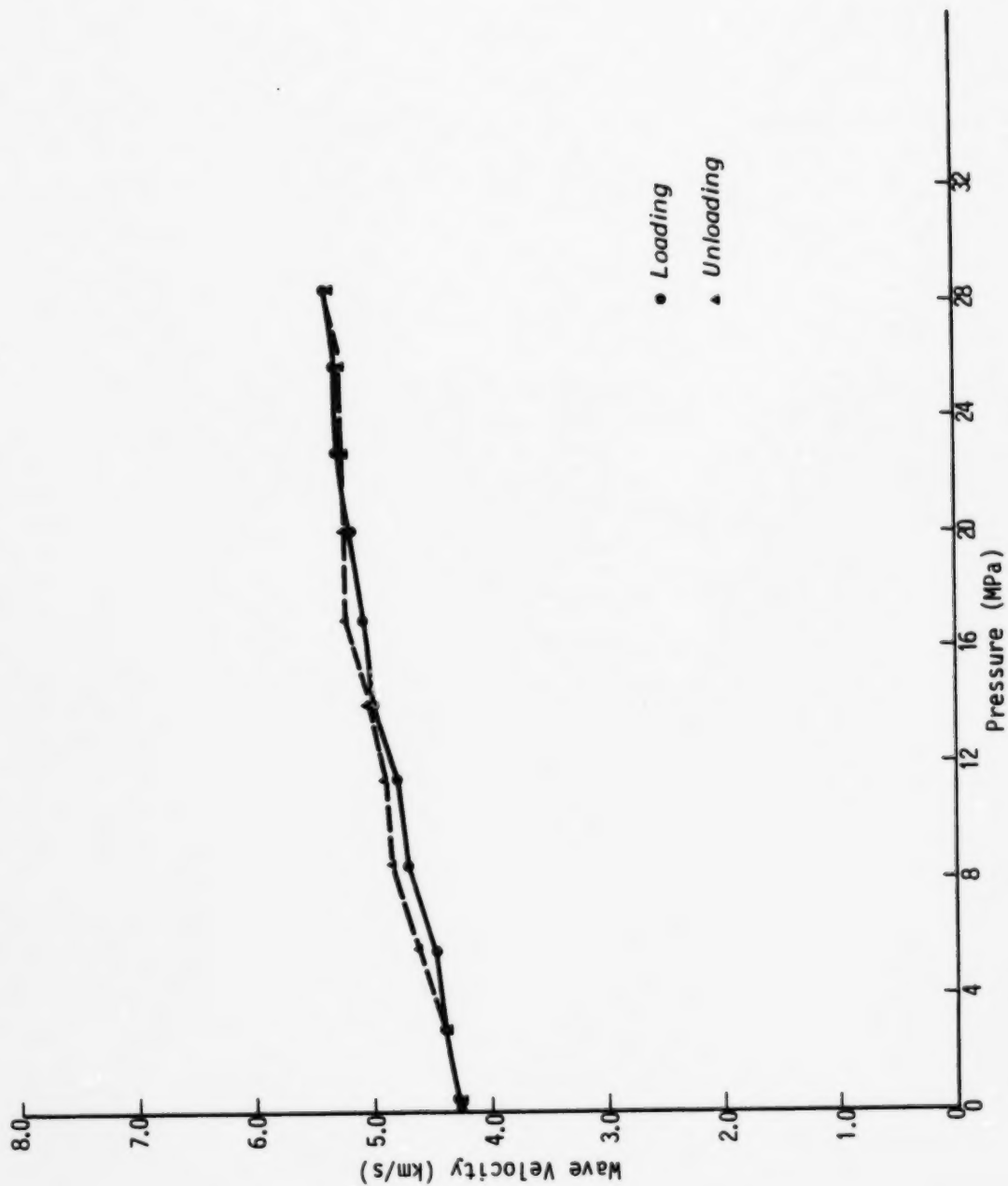
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COMPRESSIONAL WAVE VELOCITY VERSUS PRESSURE



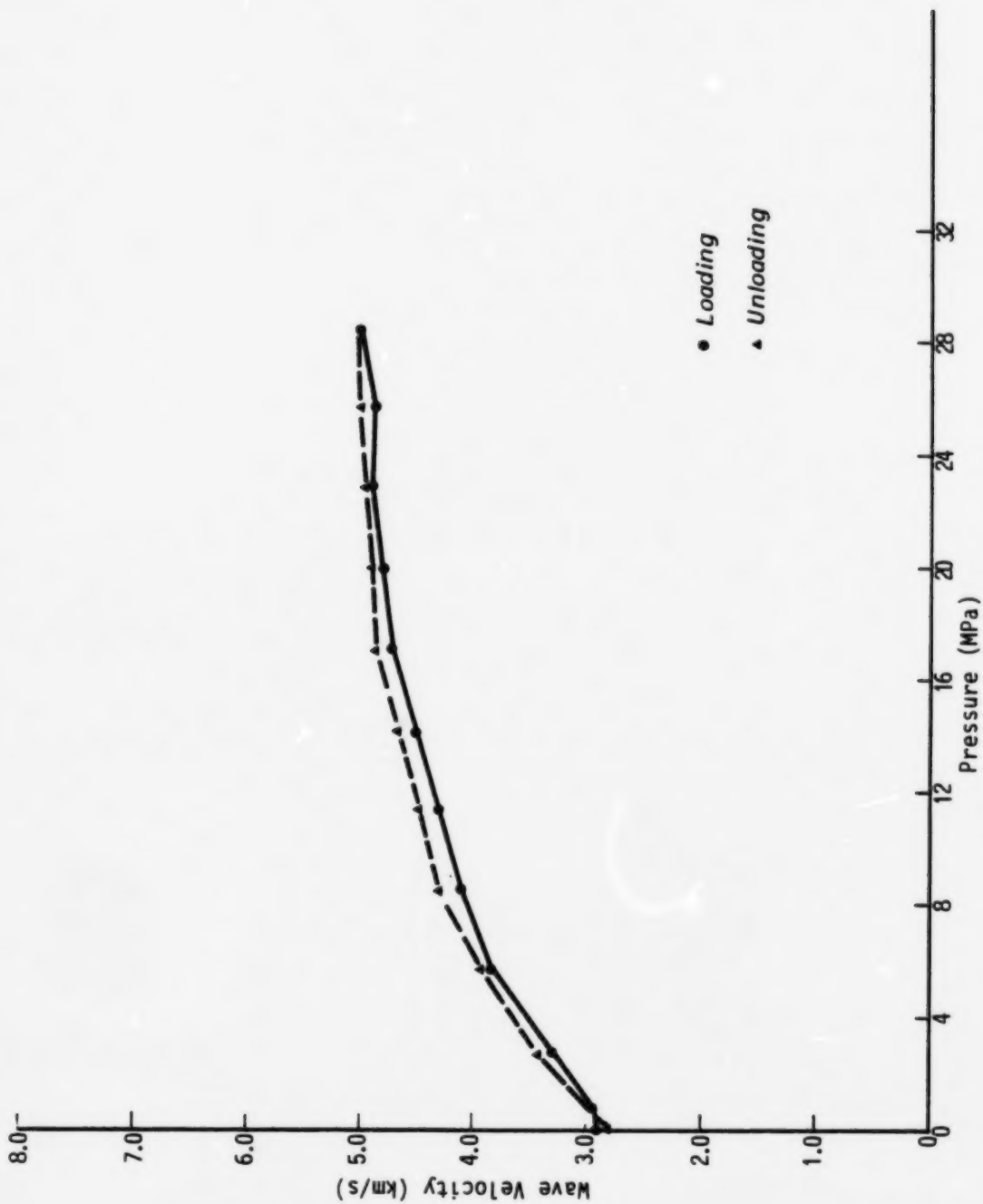
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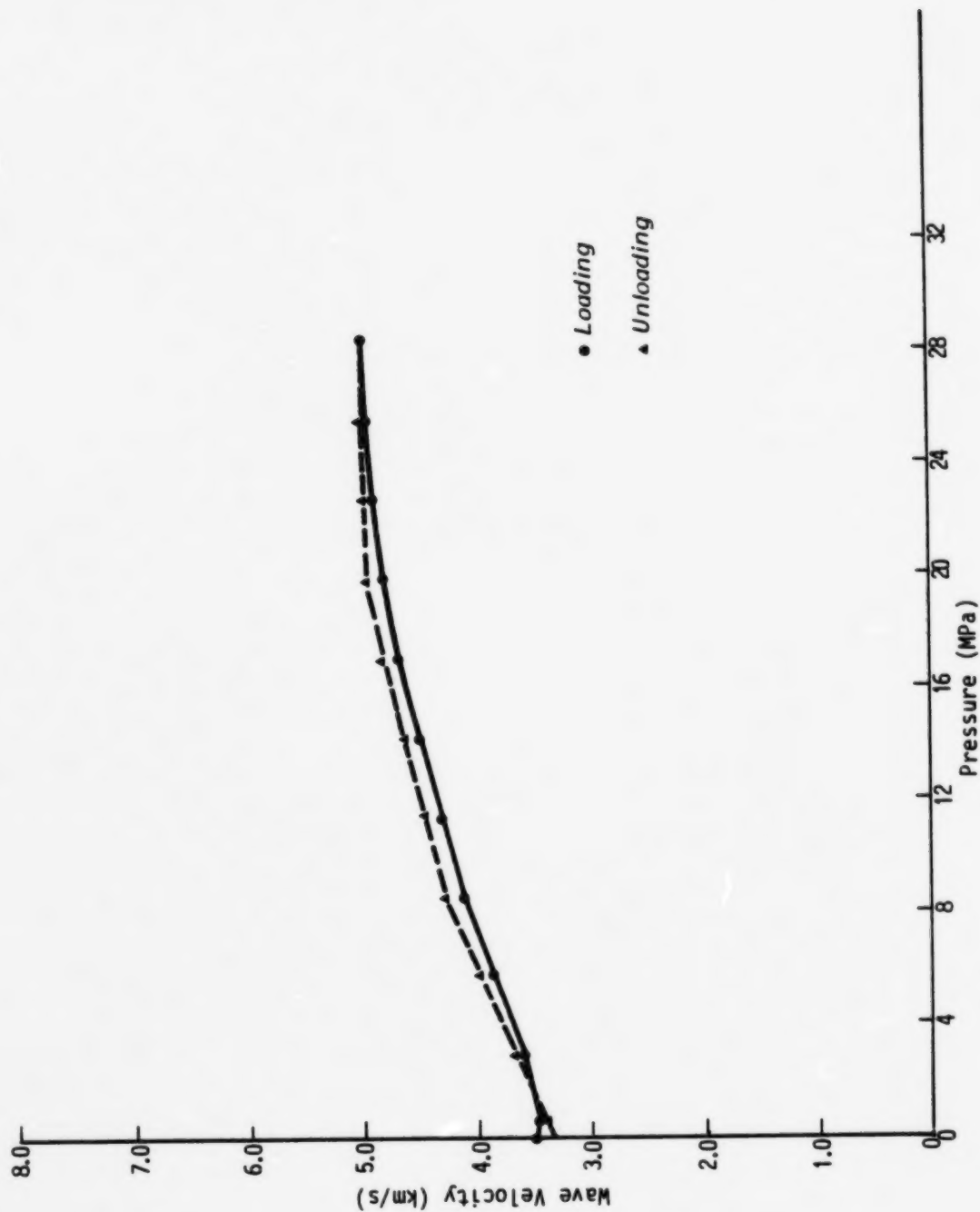
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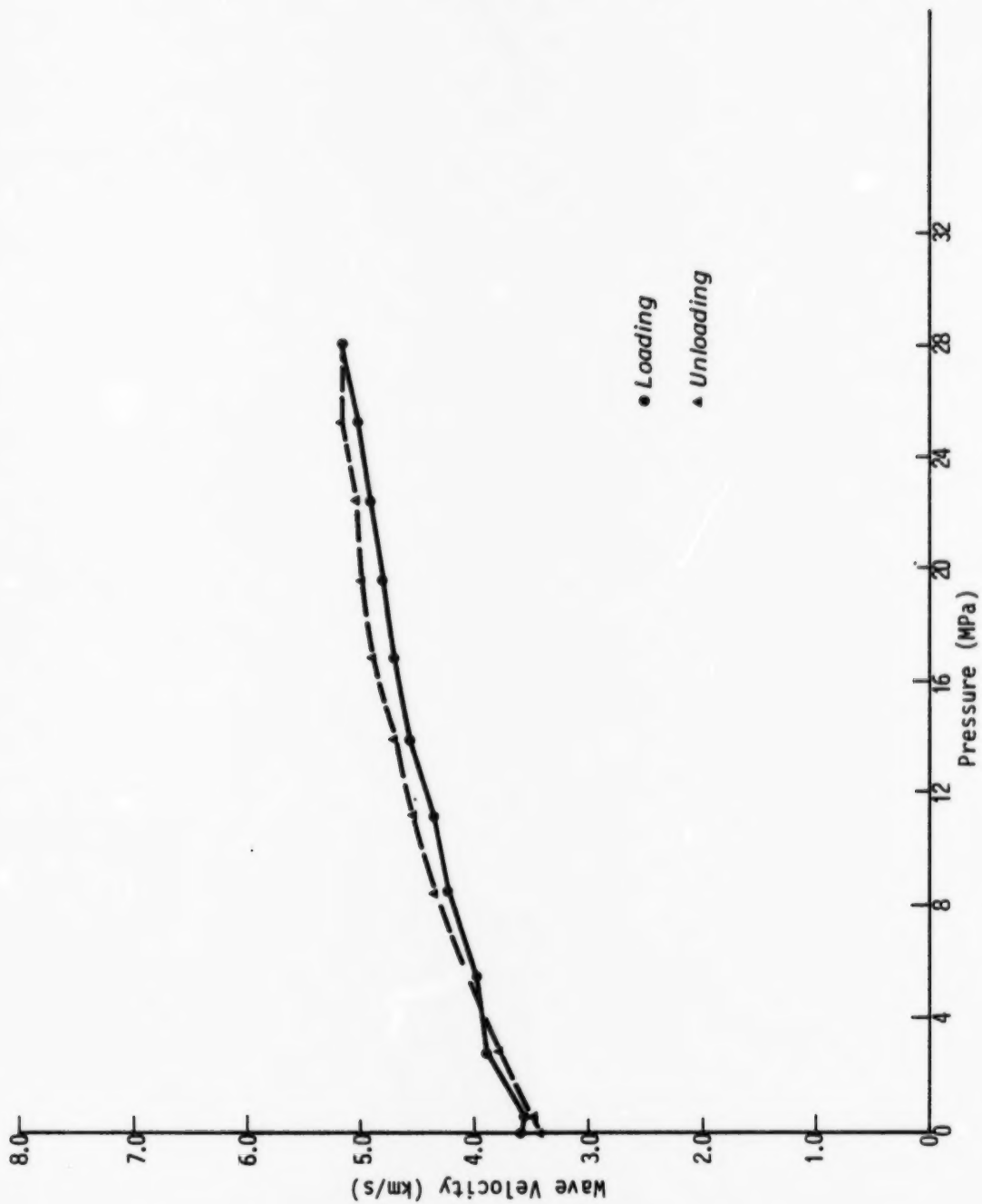
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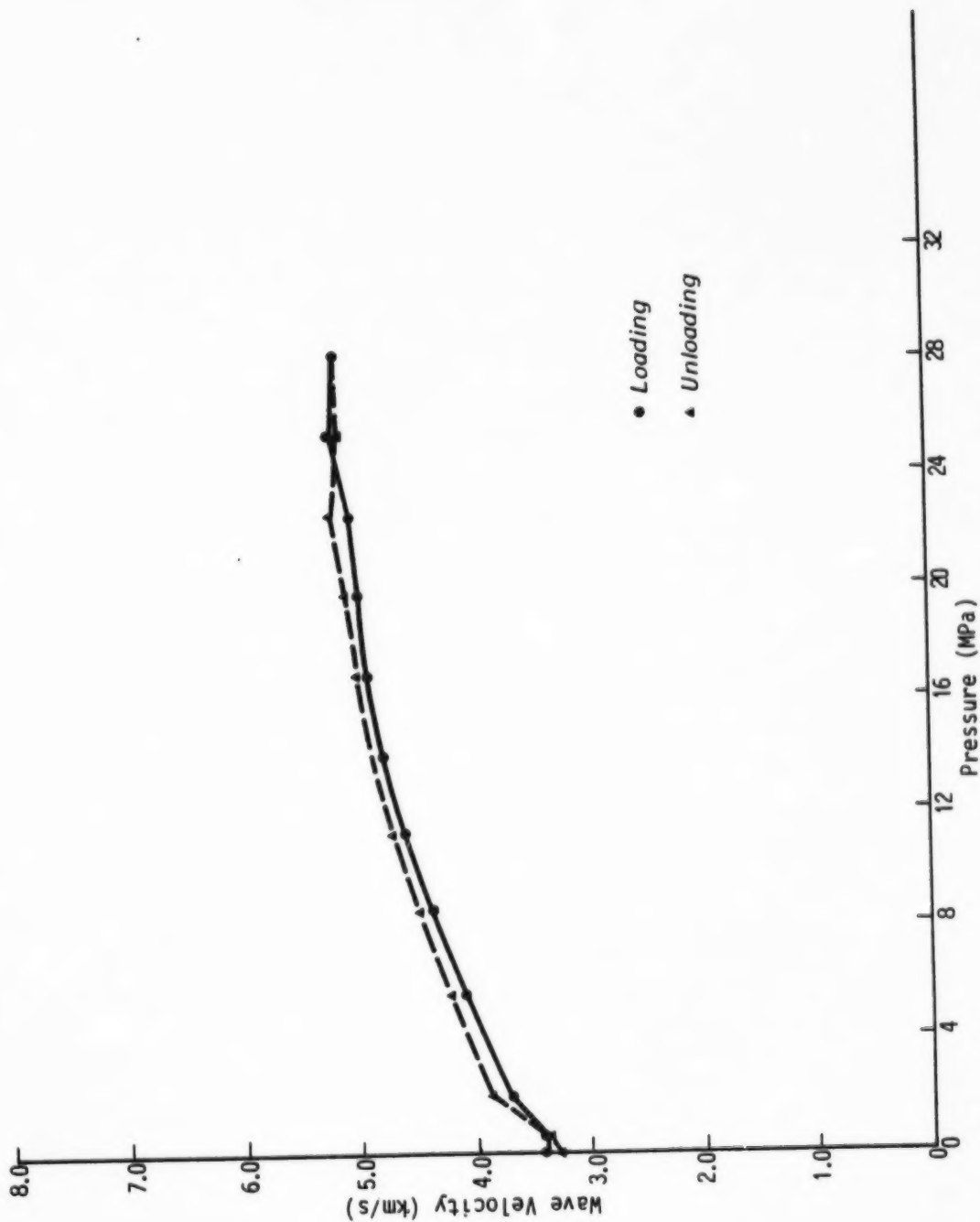
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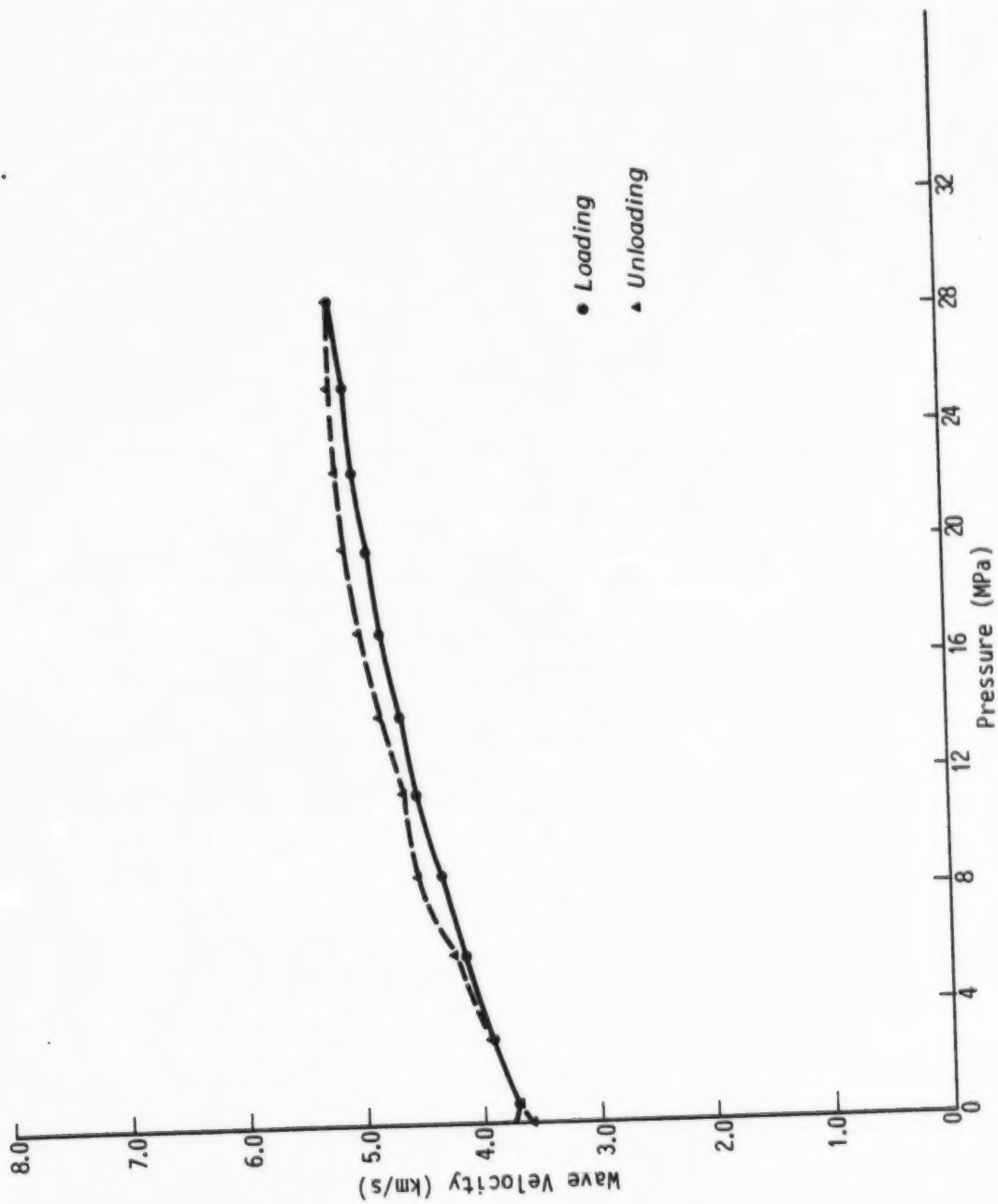
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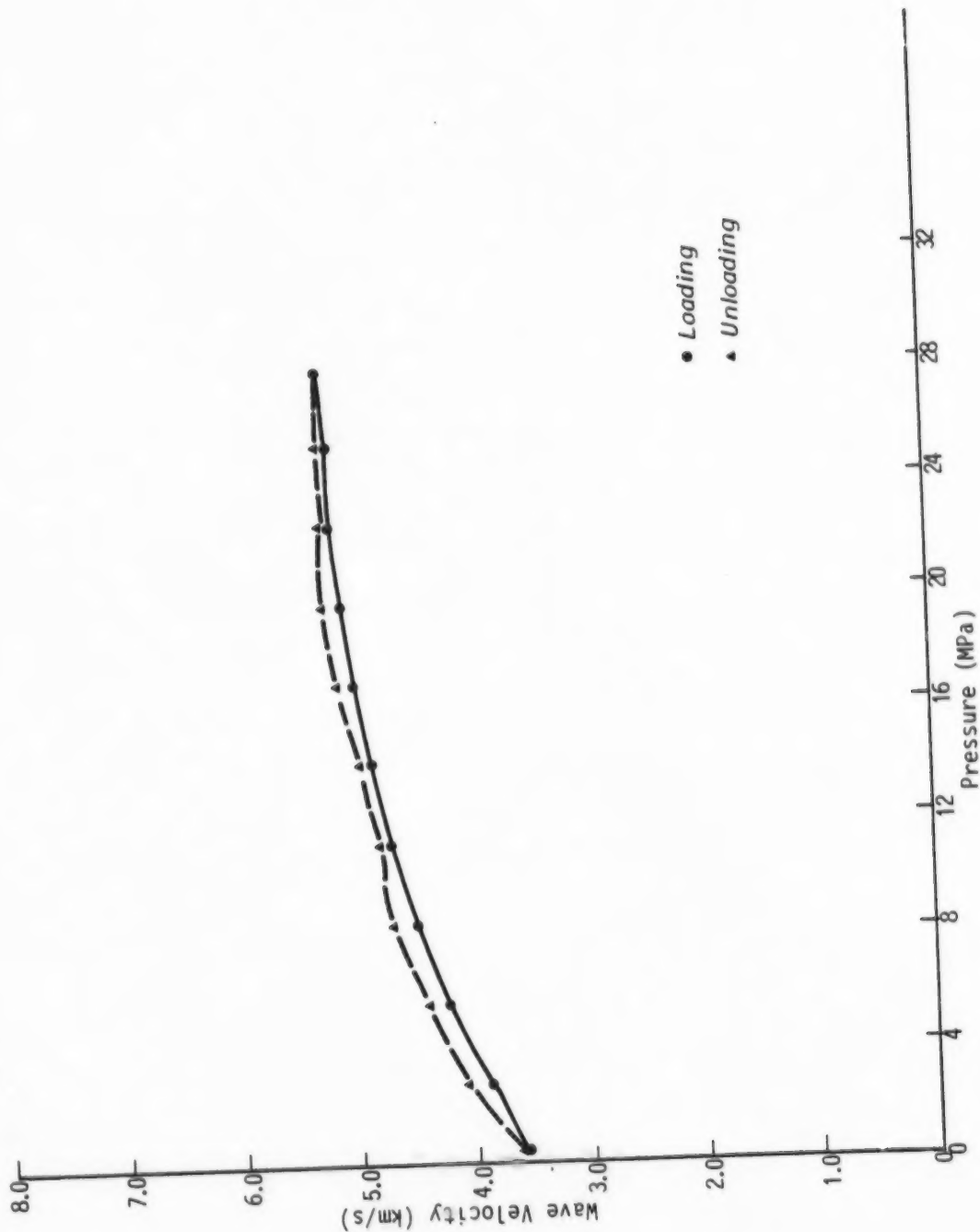
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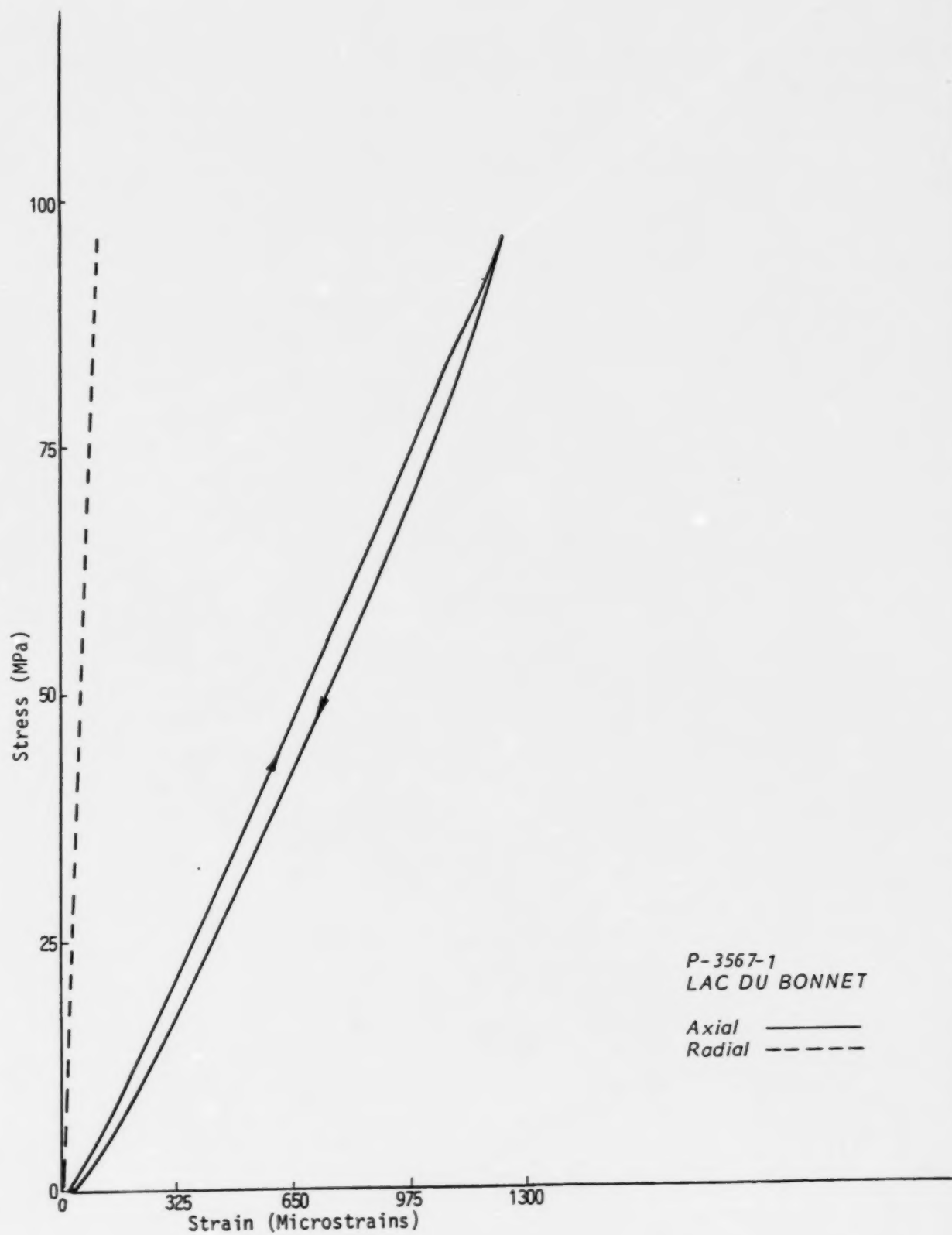


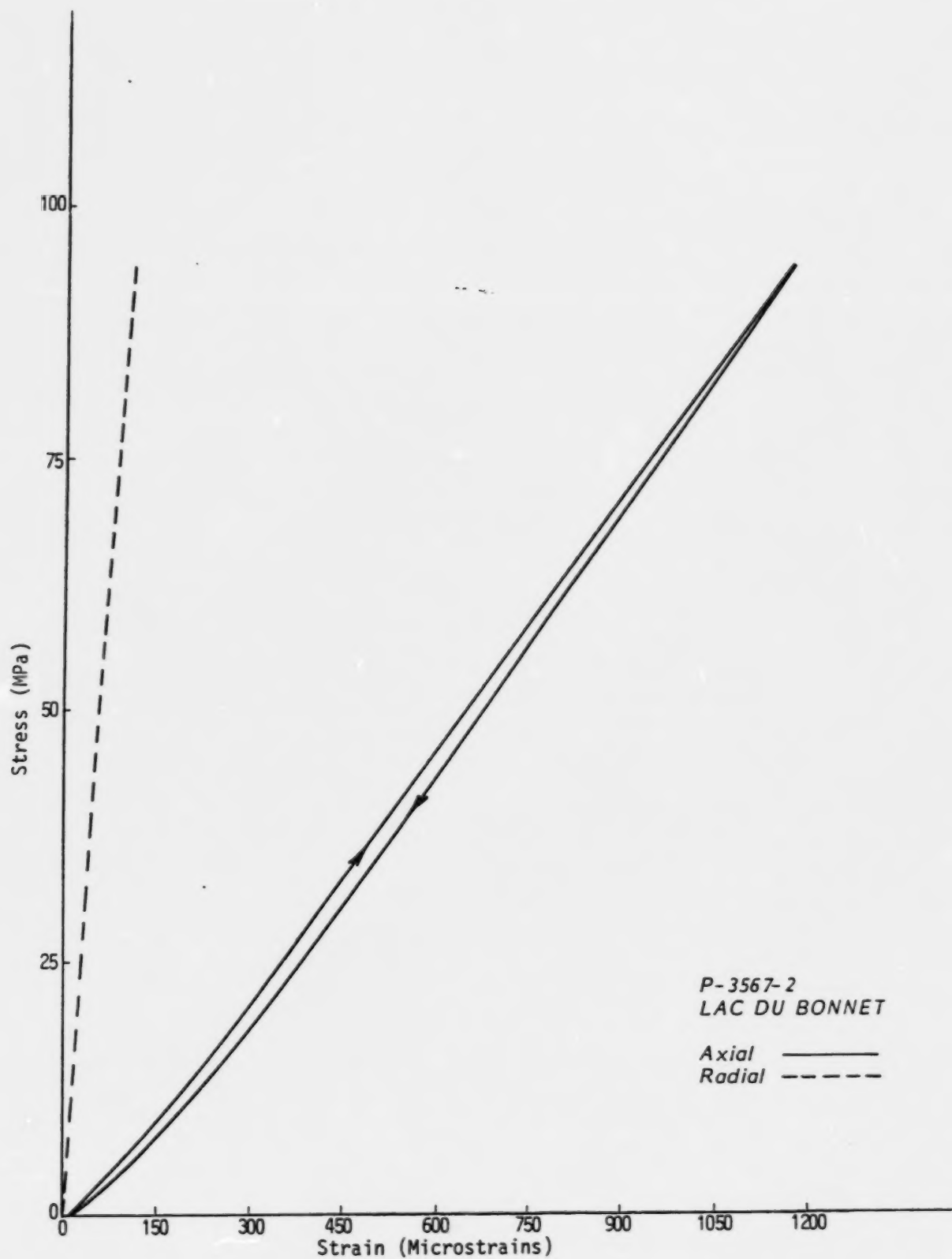
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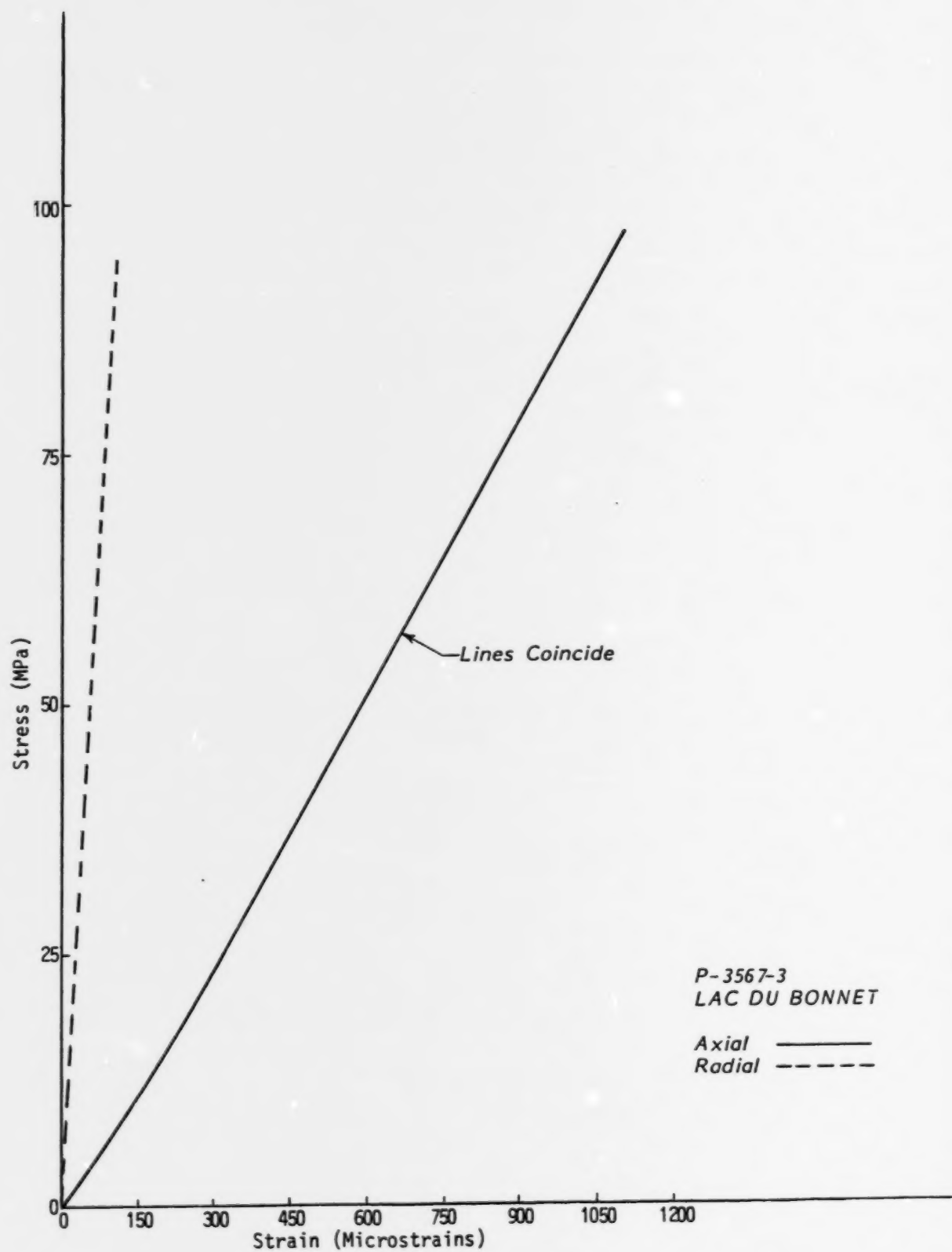


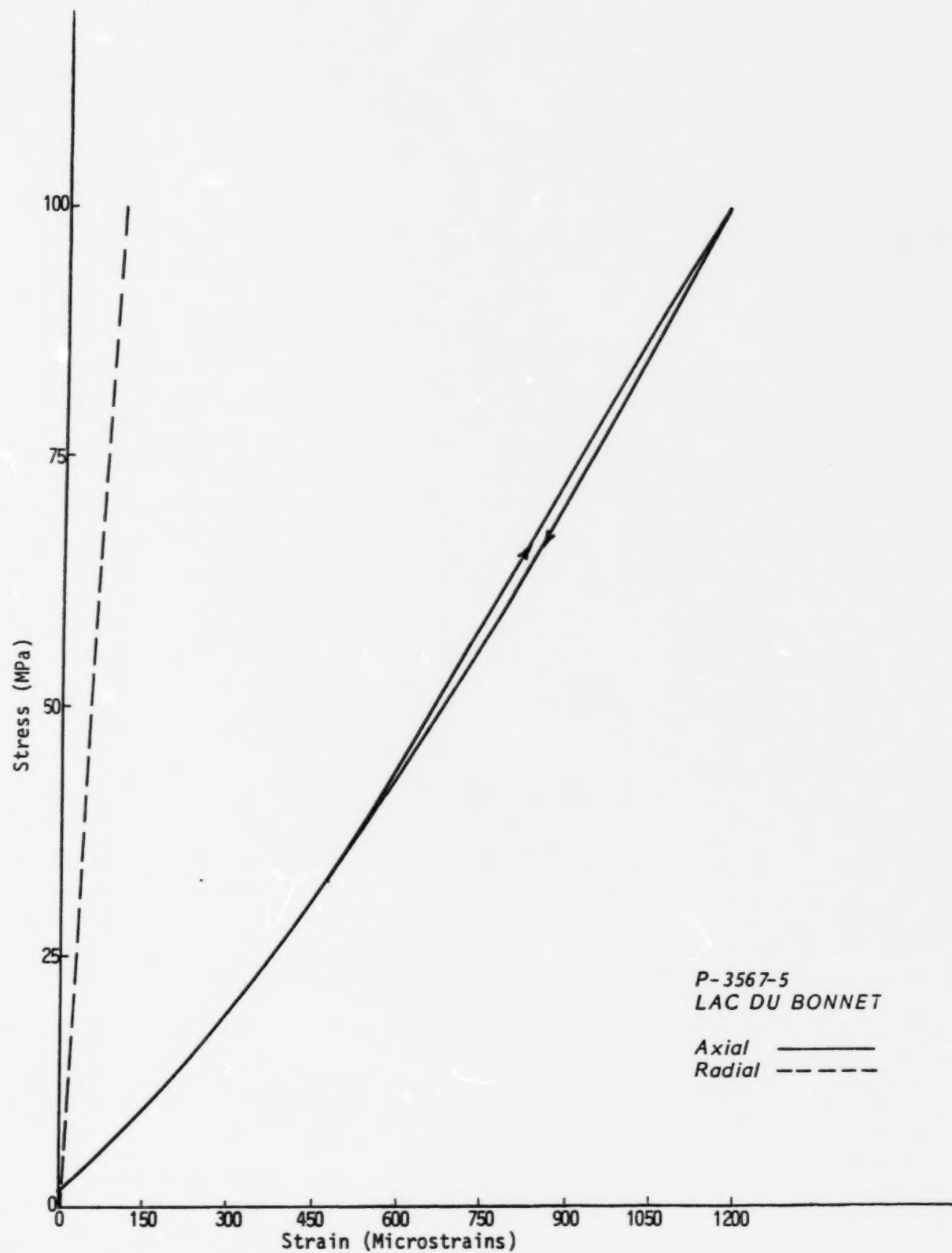
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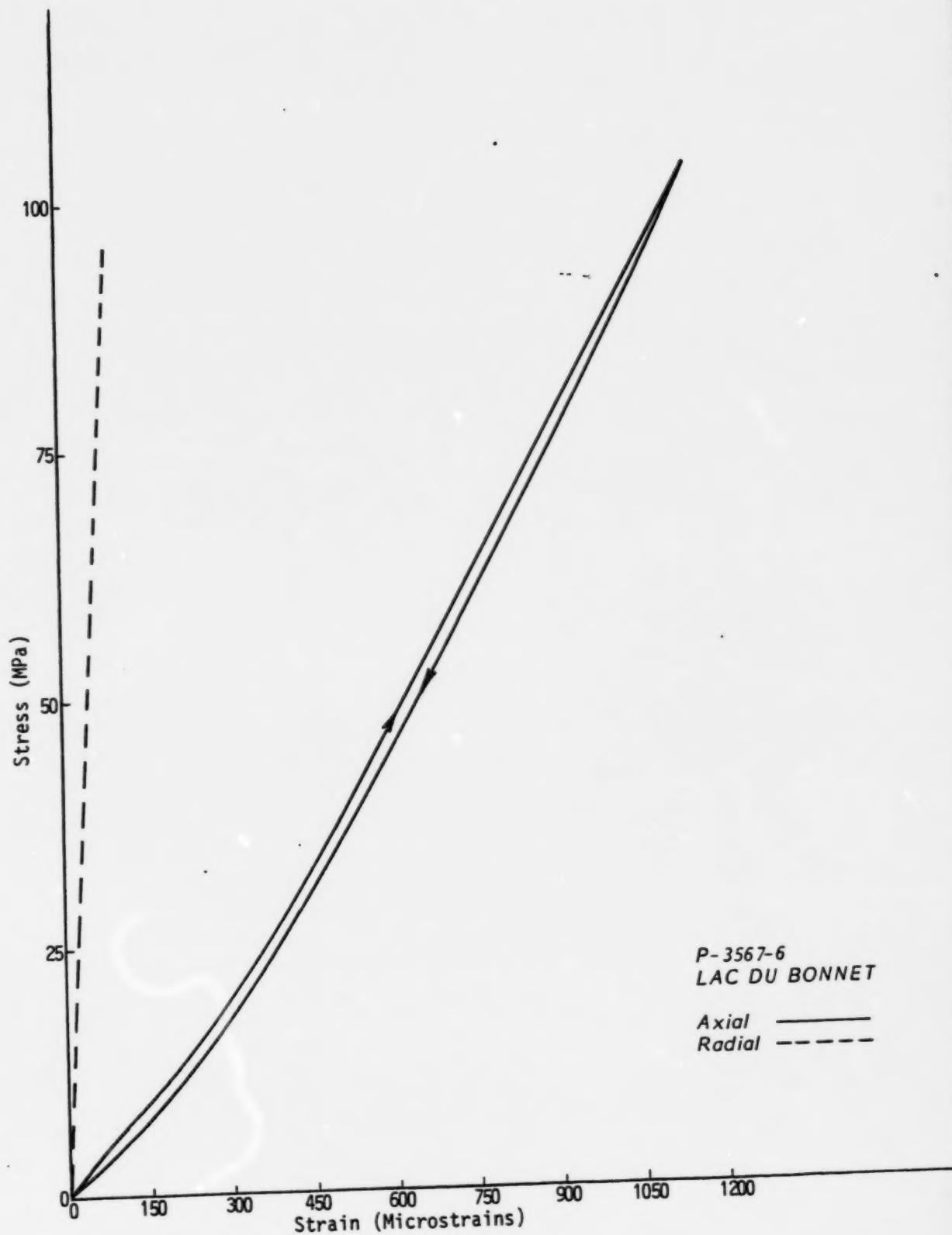
APPENDIX II





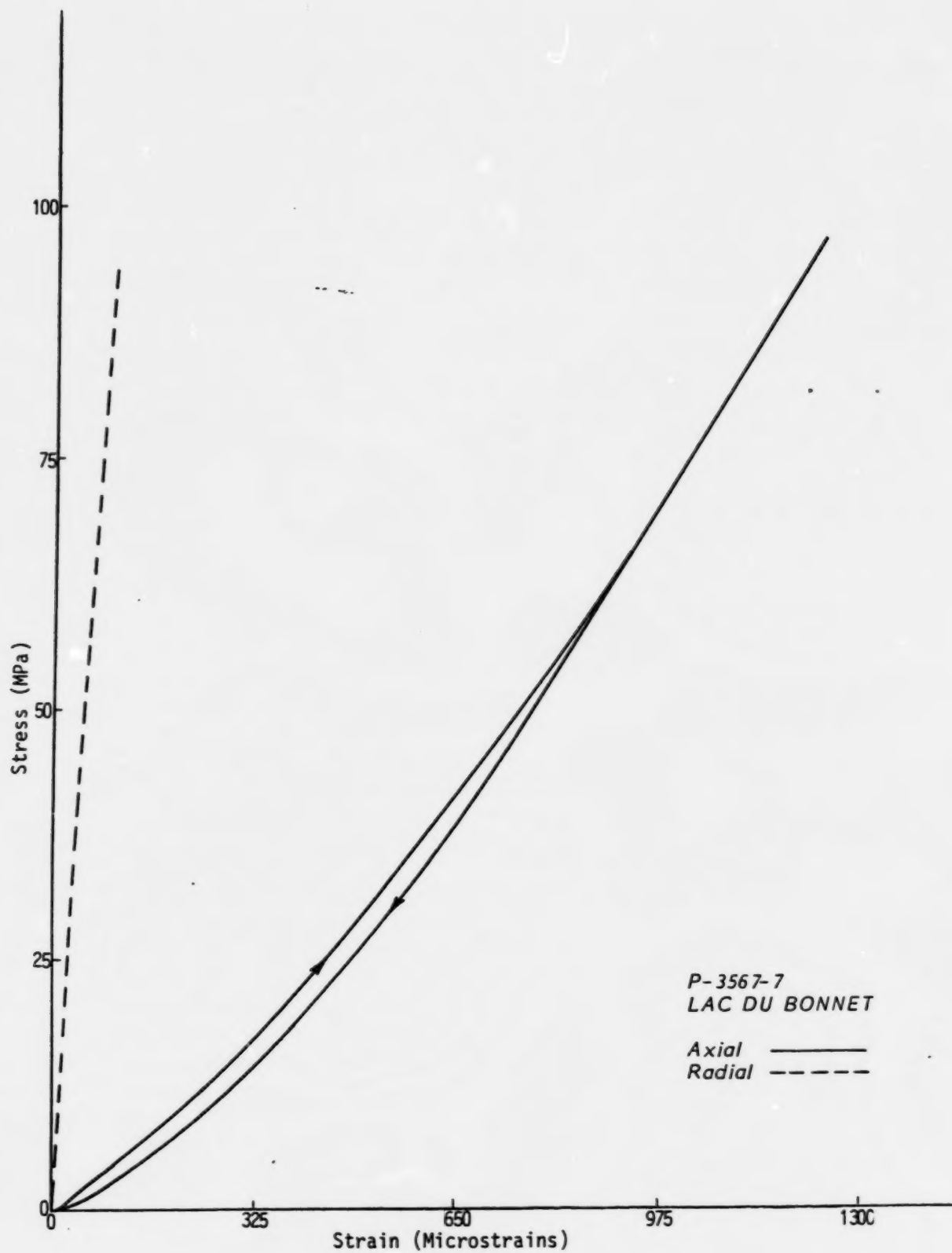


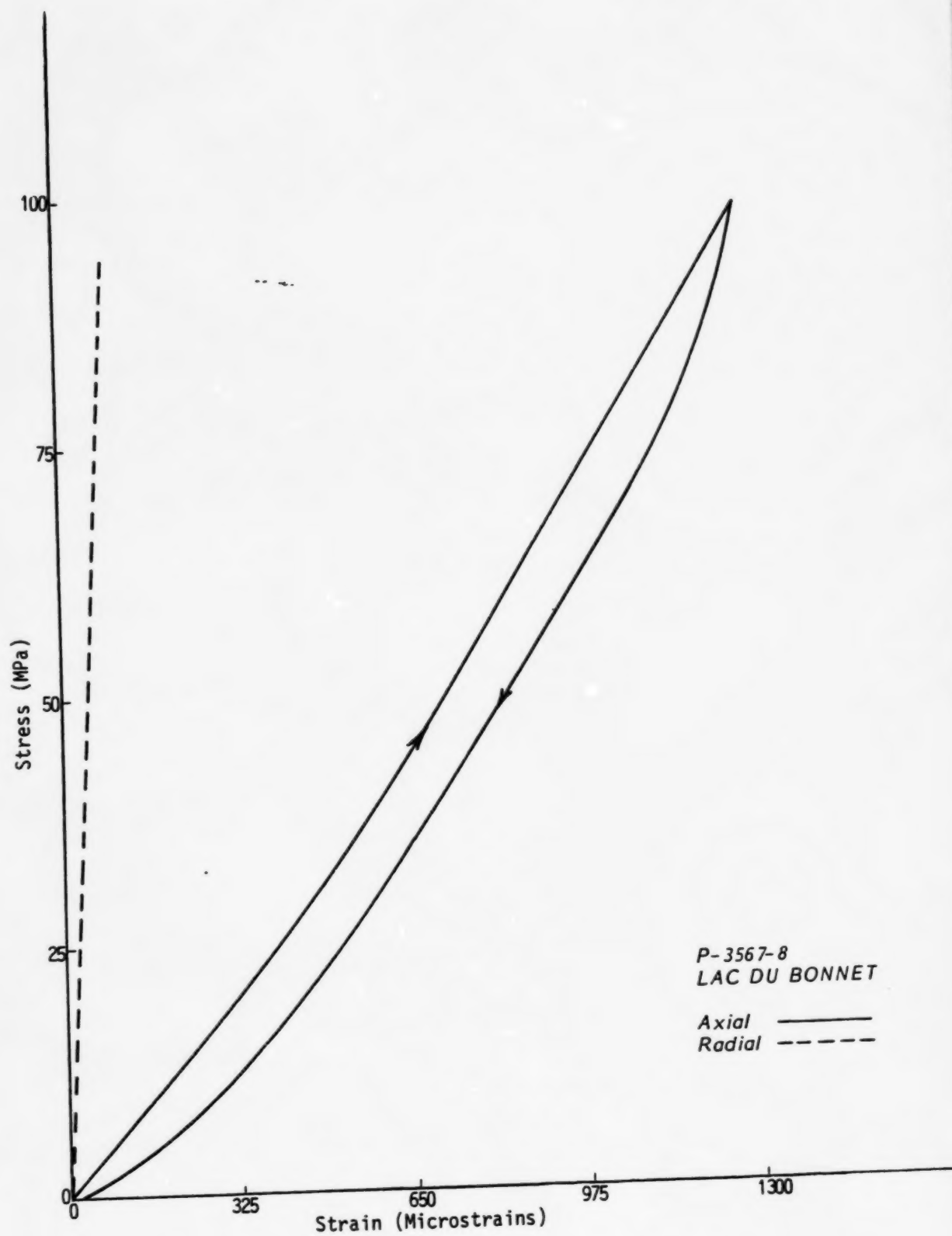


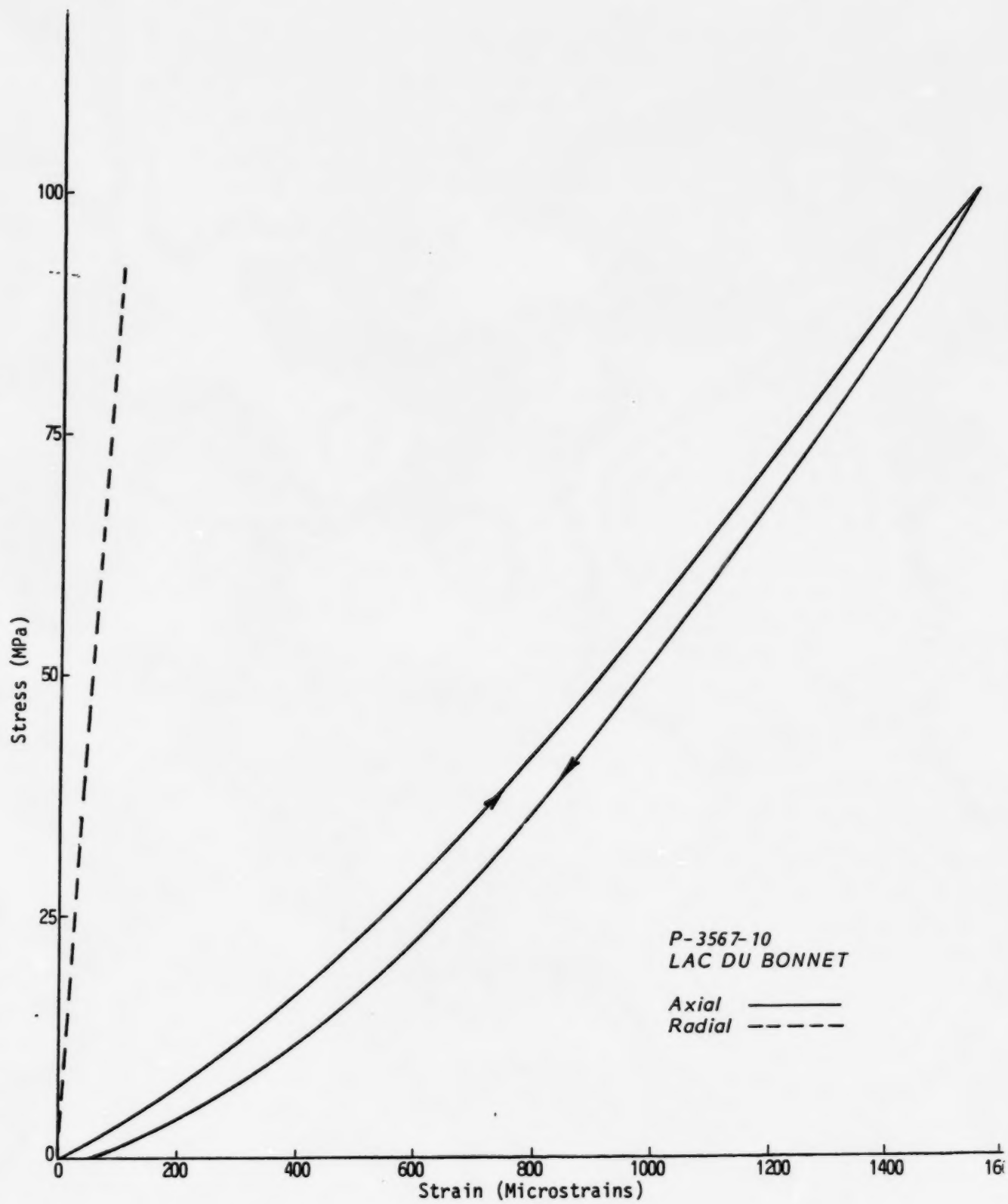


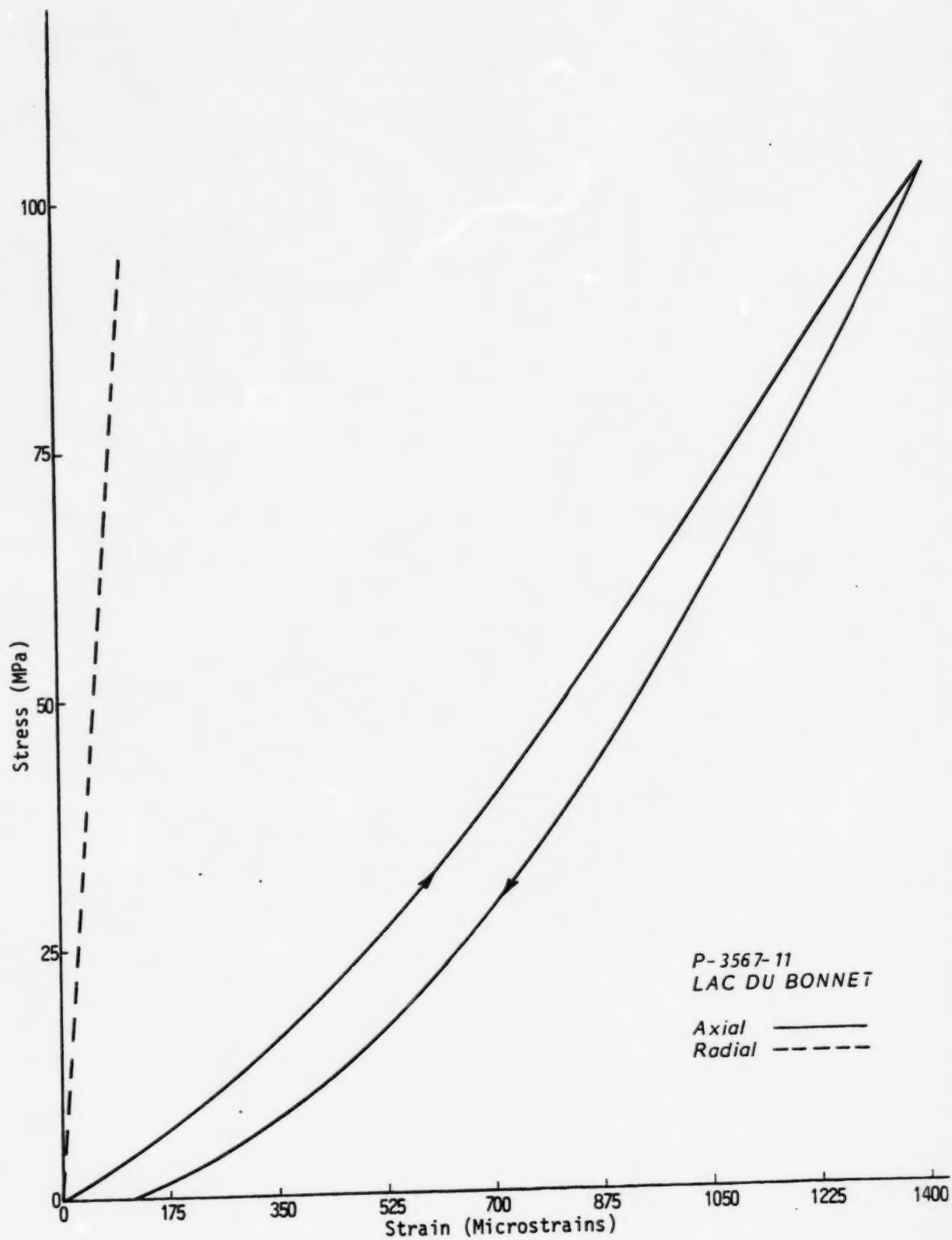
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LAC DU BONNET

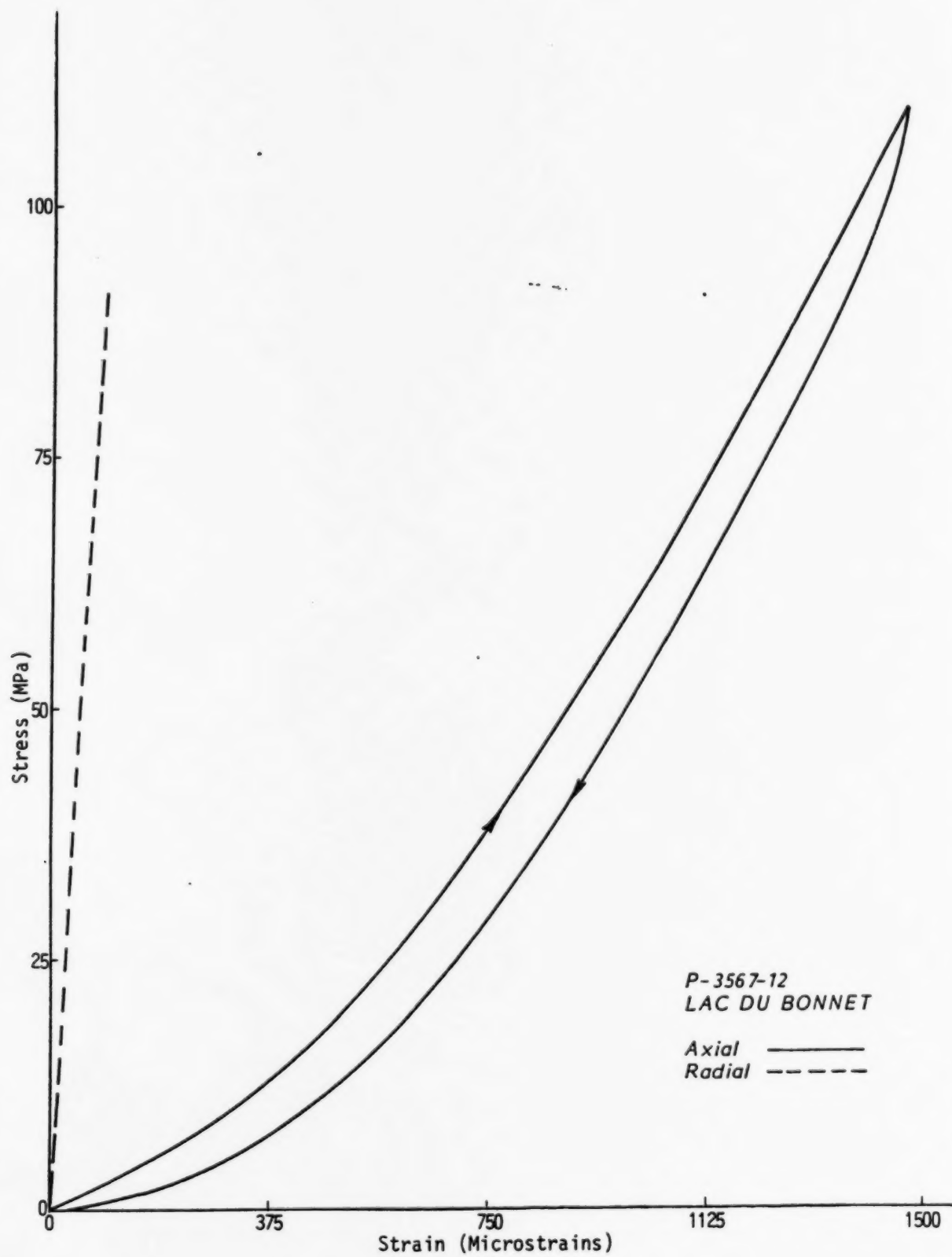
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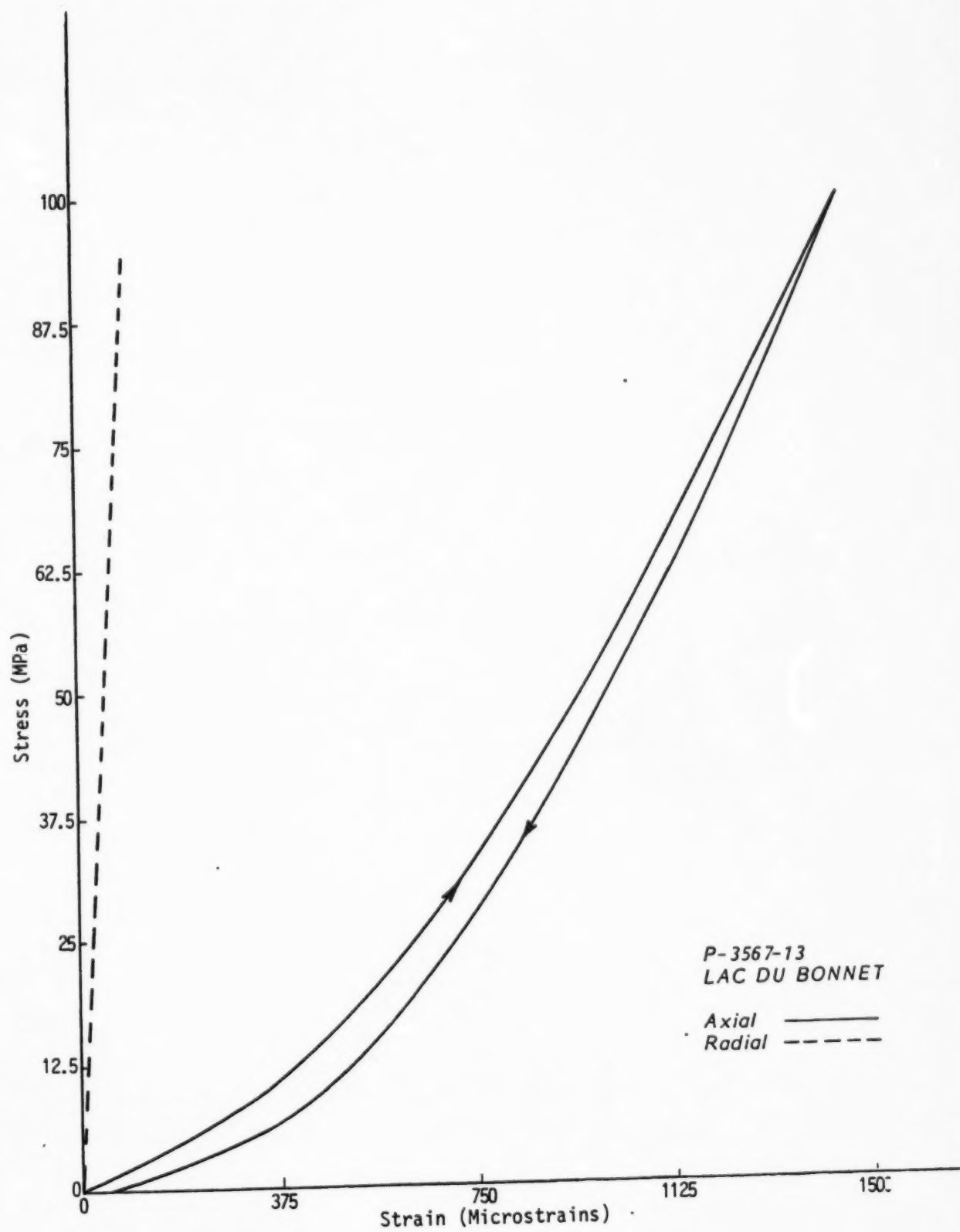


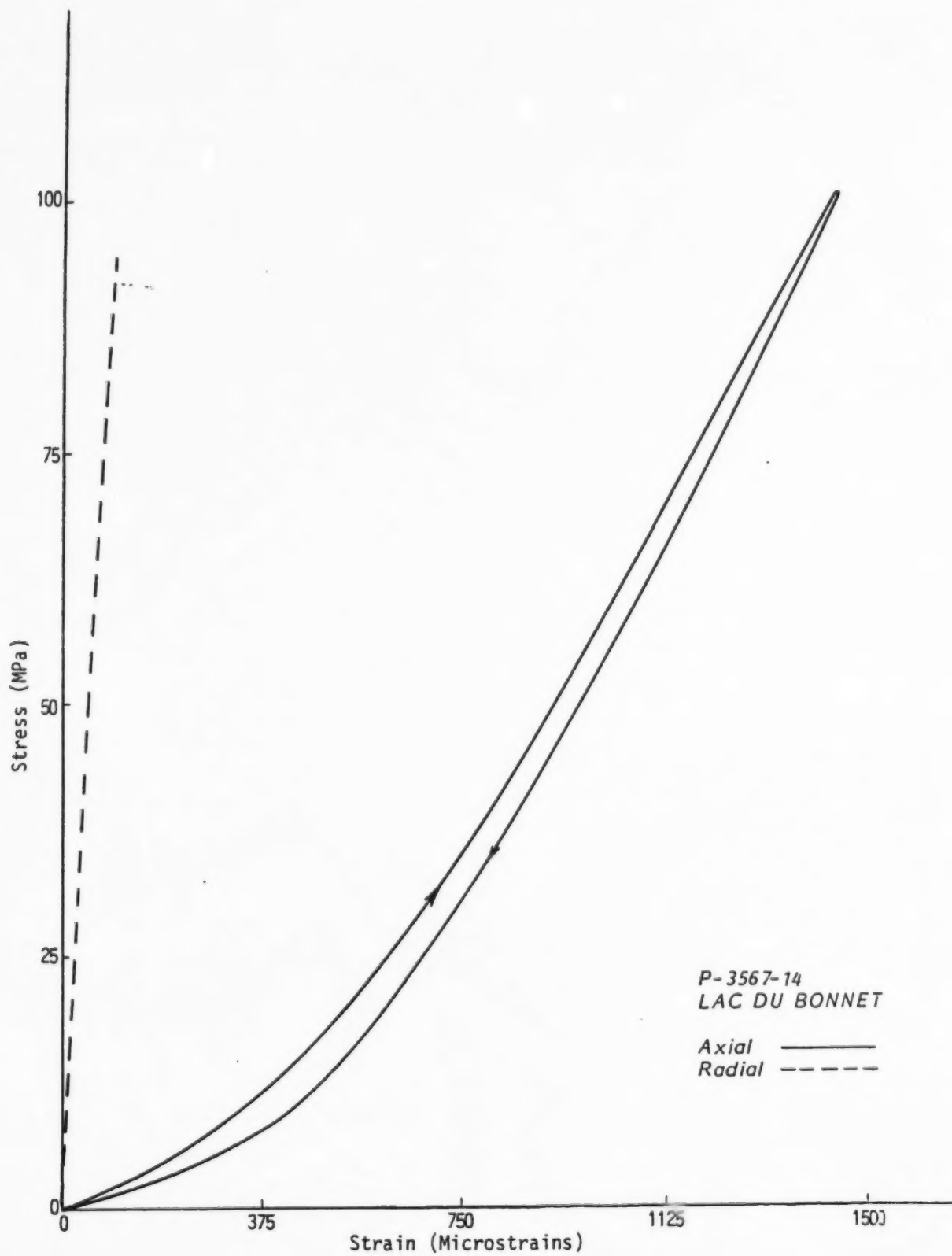


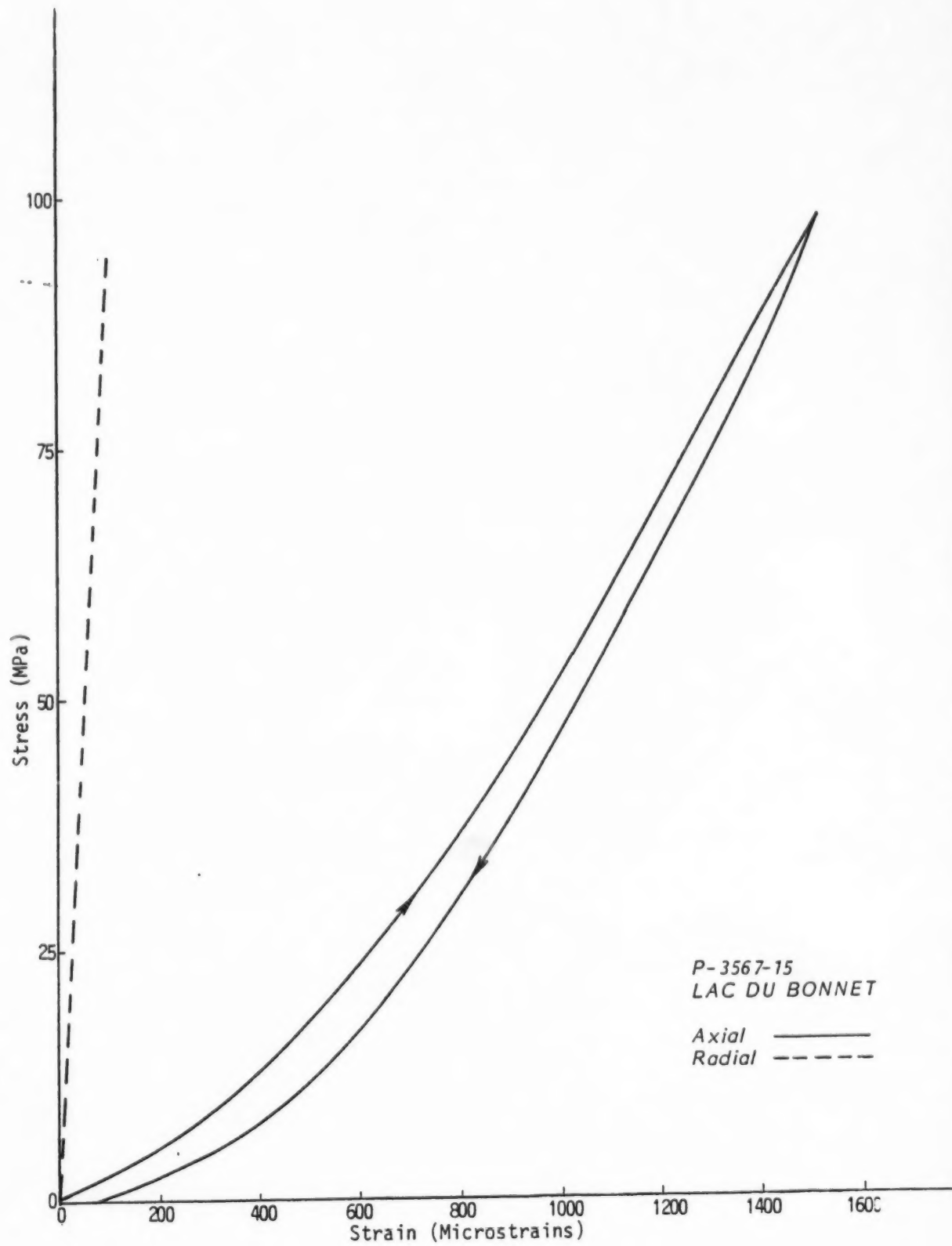


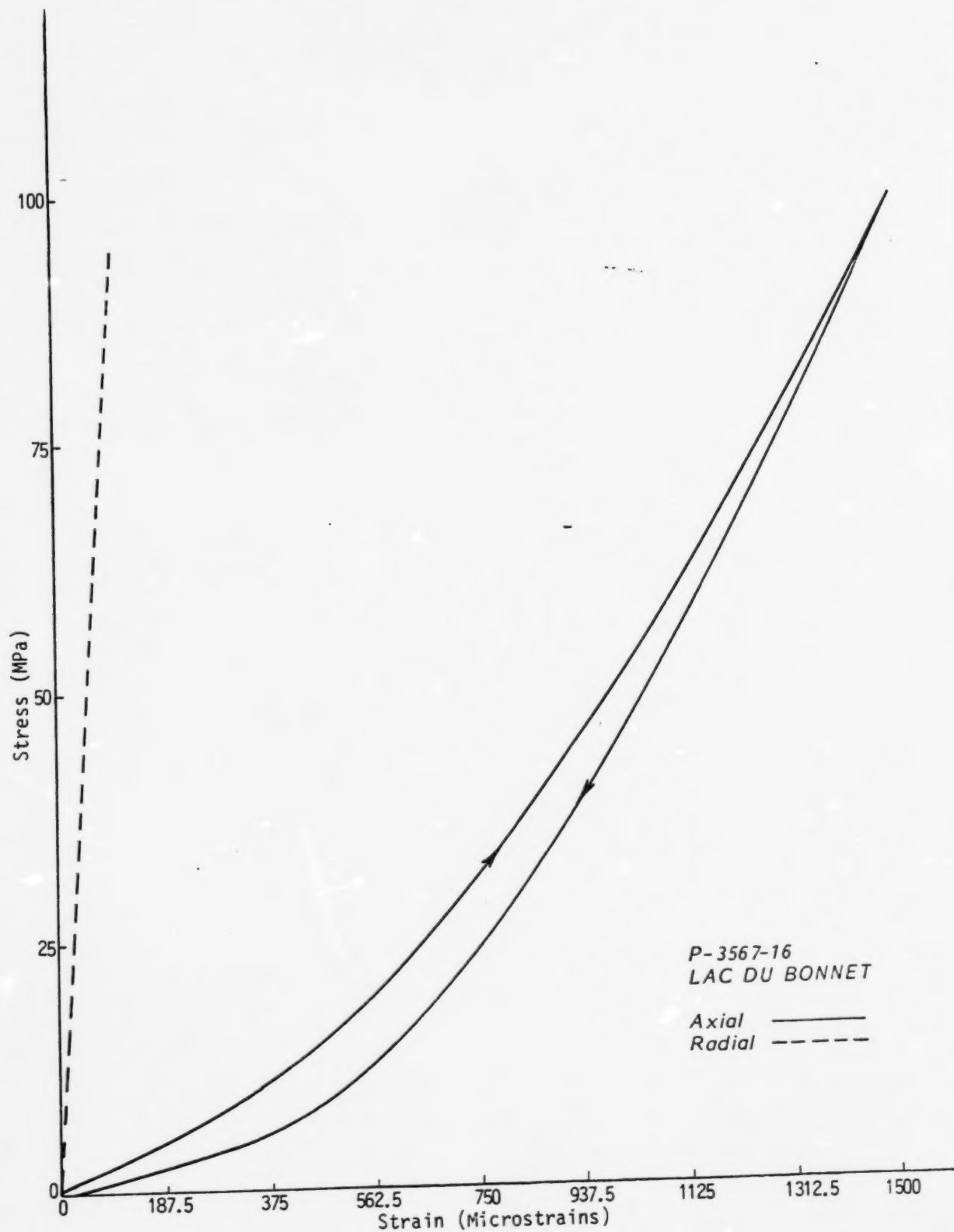












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QUALITY

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